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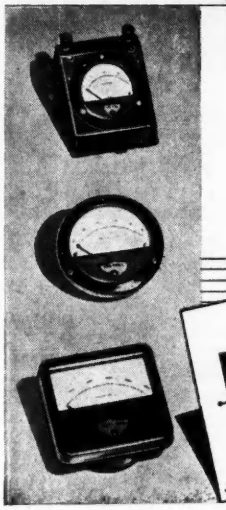

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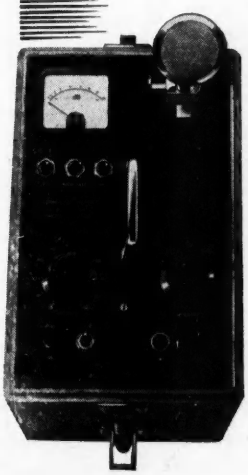

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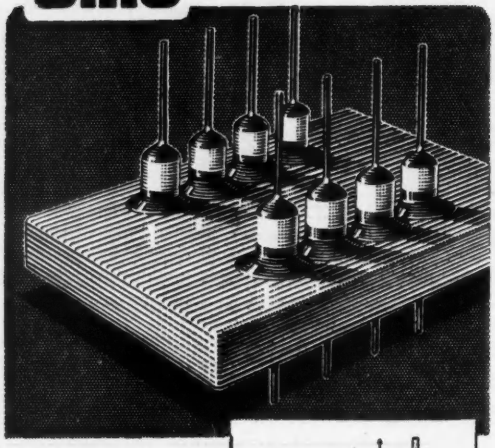

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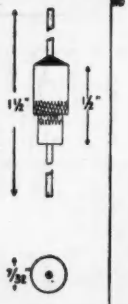

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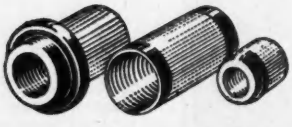

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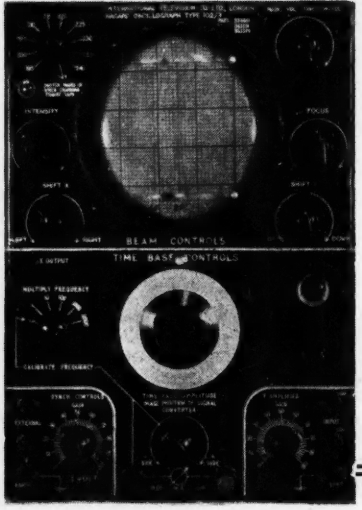

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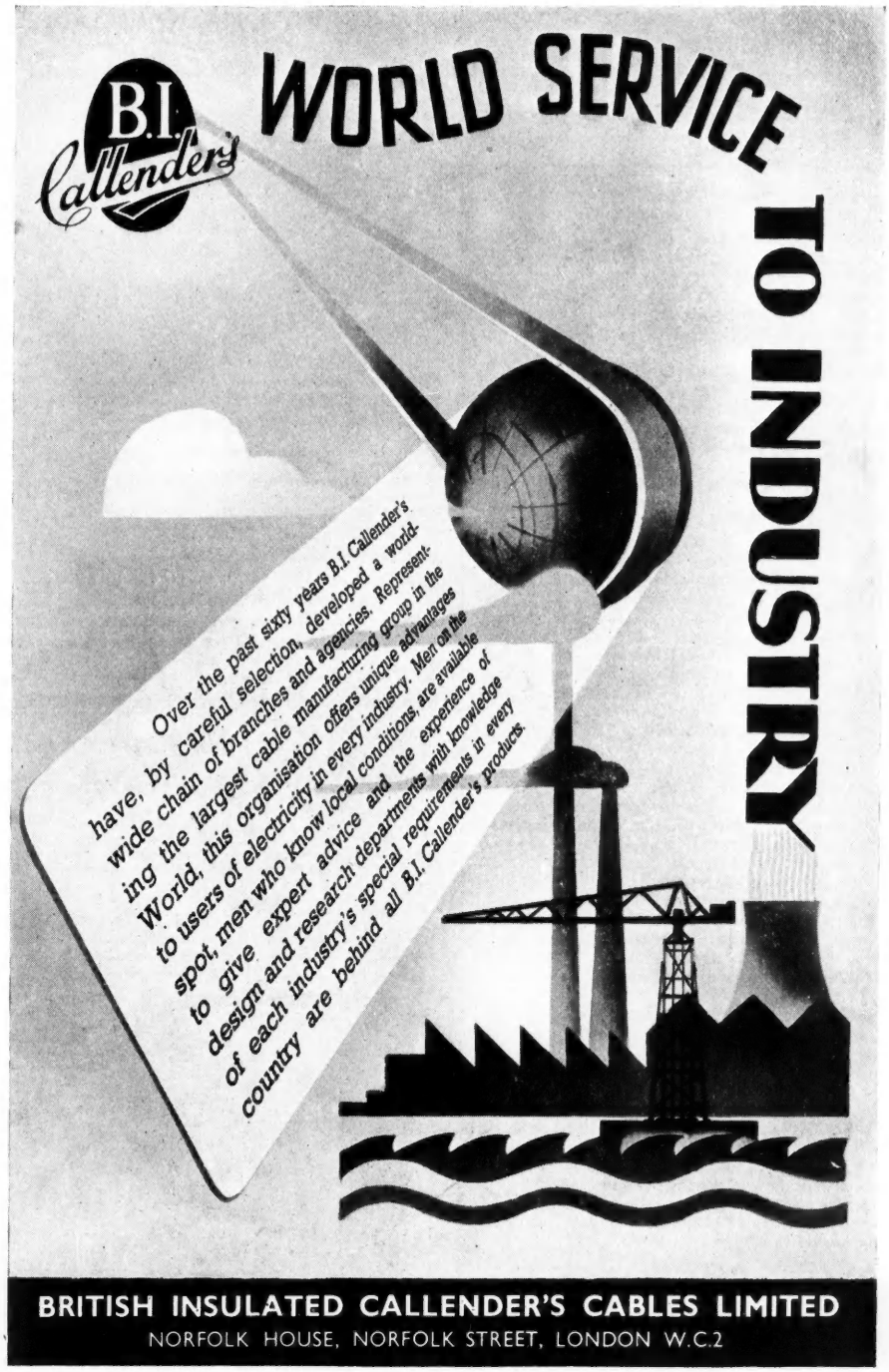
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A.24. Since the number of T.V. and "Skyrod" aerial installations has become considerable and following a period of thundery weather with lightning, the service department has been inundated with inquiries as to what users can do to protect themselves and their property against damage by lightning. These inquiries come in from members of the public, wireless dealers and wholesalers.

First of all, the nomenclature is unfortunate, in so far that a lightning conductor does not conduct or attract lightning, and a lightning arrester cannot arrest lightning.

One would expect interested people to realise that architects do not fit "lightning conductors" to chimneys, factories or other buildings to increase their chances of being struck, therefore, why should those who fit a T.V. or "Skyrod" aerial, presumably with some visual resemblance to a "lightning conductor," expect increased danger?

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Readers who have visited Switzerland (and presumably other alpine countries where isolated wooden buildings are commonplace) will have noticed two or three spikes several feet high on roofs of isolated hillside dwellings; these are not aerials but "lightning conductors" to minimise the risk of a strike which inevitably would result in fire.

If a house is struck, in nine cases out of ten, it is a chimney that takes it. Technically this is due to the column of ionised (slightly conductive) warmer air which—winter or summer—is rising from it and drifting away down-wind, ultimately rising far above any aerial. This is happening from every house all the time, therefore when a house is struck, the first solid matter encountered by the charge is the chimney, which is usually shattered. Sometimes the charge travels down the chimney shaft and damages the decorations of the rooms *en route*. If the unfortunate house is on the 'phone, the wires are generally fused, in spite of the proven *1 "lightning arrester" fitted by the G.P.O. *All this happens whether or not there is an aerial lashed to the chimney.*

When you take into account the many millions of houses, and the odd one or two that are damaged by lightning, you realise that the risk is negligible. As tangible proof of this, damage by lightning is generally included in every householder's comprehensive insurance policy, and no increased risk is recognised by the addition of an aerial, T.V., "Skyrod," or horizontal.

As an additional "vote of confidence" every Belling-Lee aerial system is insured by us for a period of twelve months, up to a sum not exceeding one hundred pounds, against damage to the aerial system or radio or television receiver due to lightning. Following normal procedure, this comes into operation only in the event of there being no collateral insurance or after any existing insurance cover has been exhausted.

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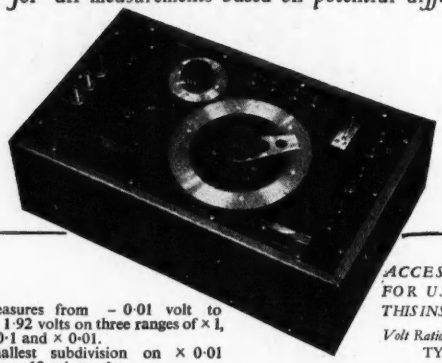

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Electronic Engineering

JULY, 1947

Volume XIX. No. 233.

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Functional English

THE excellent course of lectures on "The Presentation of Technical Information," recently delivered by PROF. R. O. KAPP at University College and the I.E.E., have, to coin a phrase, filled a long-felt want. Judging from the audience, it is not only the student who feels the need for guidance in correct expression, and many experienced engineers have been stimulated by PROF. KAPP'S views on what constitutes clear and precise technical writing.

For some reason, as many have remarked, the average engineering student considers that he has absorbed all the English that he is likely to want during his schooldays, and it is only when he is faced with the job of preparing a concise and readable report that he may wonder whether the conventional teaching of grammar and syntax has really fitted him adequately for the work.

There is a definite technique in the writing of scientific reports and articles which need not be considered as a 'gift'—it can be acquired, and sometimes is, by the painful process of having manuscripts rejected or reports edited by one's superiors. A better way is to recognise that writing English is a subject to be studied with as much care as drawing diagrams and to include it in the curriculum of engineering training in future.

It might be argued that an attempt to formulate the use of functional English would lead to stereotyped writing and a monotonous uniformity in technical articles, but these are just as much a fault of expression as excessive verbiage or ambiguity. The trained writer will know what to avoid and at the same time will show his individuality in clearness and use of the correct word. As PROF. KAPP points out, the use of vague expressions generally indicates that the writer has not thought out the correct words and is taking the line of least resistance. (Incidentally, he may be afraid of committing himself, like some Civil Servants in their correspondence, but that is another matter.)

It is time that some of the woollier phrases—and readers may amuse themselves by picking them out of technical publications, this periodical included—were listed under Technical Clichés in a new edition of Fowler's book.

There are many engineers who will not have an opportunity of attending lectures on the subject of how to write clearly, but they can still improve their style and clarity by doing two things. The first is reading. The technical man who says, "I have no time for reading," has nothing to be proud of, although he generally says it as though he had. The second is also reading—one's own writing from the point of view of the reader.

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from the present owners, Hulton Press Ltd., commencing with the August issue.

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UNIT CONSTRUCTION CONVEYOR SYSTEM

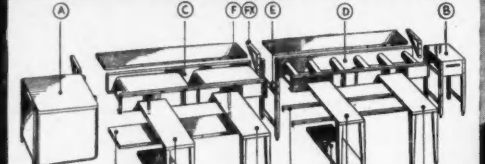
The " Flowline " Conveyor System has been designed to provide a complete assembly organisation which can be adapted to any production sequence or layout. By means of the unit construction shown in the sketch below it is possible to carry out the operations of transporting, processing, assembly and packing with the maximum flexibility, allowing for extensions or modifications at any stage.

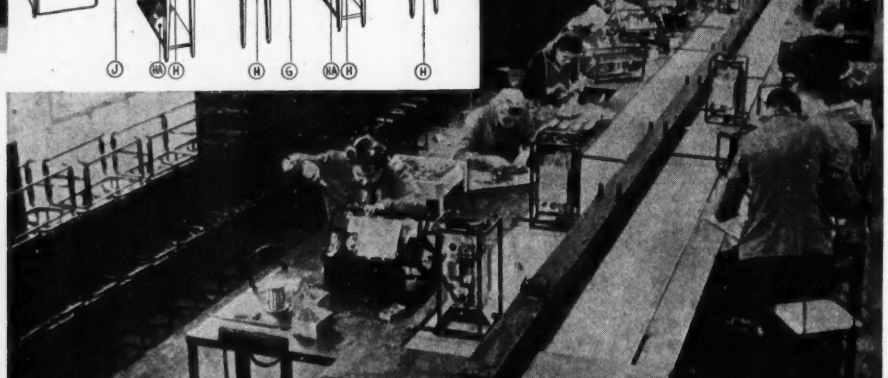
The conveyor in its simplest form consists of four interchangeable units : Drive, Tension, Trough and Stand. For assembly operations four additional units—side bench, footrail, side table and undershelf—are added at convenient points. The standard conveyor is made up from multiples of 6 ft. in four widths of belt, and the only limit on length is the total load on the conveyor, which must not exceed 2,000 lb.

Ingenious features of the system are the use of the return side of the belt to carry empties or other parts if required, and the use of a separator unit to prevent contamination of the finished product by replacing it on a dirty belt.

The photographs show (top) the drive unit and side tables at the end of a system for assembling vacuum cleaners, and (below) a double belt system used for assembly of chassis.

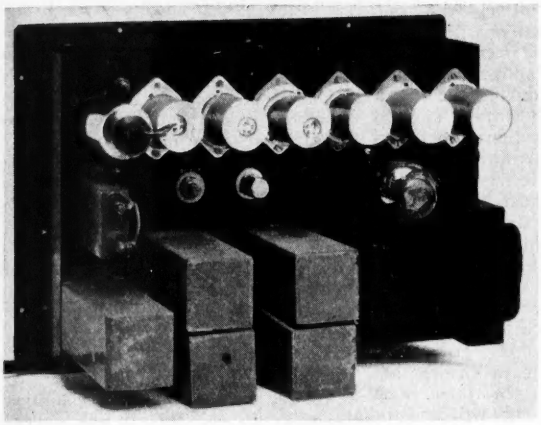
By courtesy of Messrs. Fisher & Ludlow Ltd., Rolfe Street, Smethwick, Staffs.

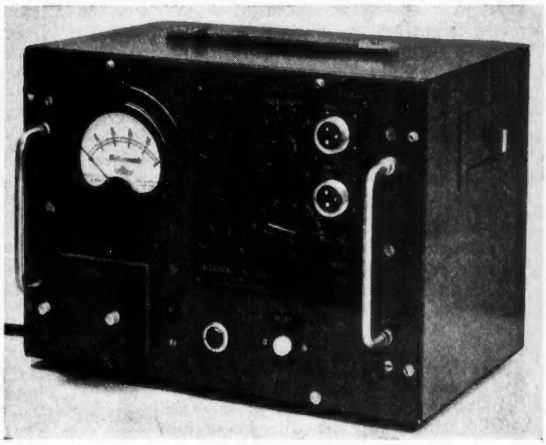




Key to Diagram

- A Main Driving Unit.
- B Belt Tensioning Unit.
- C Belt Troughs, 6 ft. long.
- D Roller Troughs.
- E Pressed Steel Stands.
- F Side Benches, 5 ft. 10 in. by 1 ft. 3 in.
- FX Side Bench Bracket.
- G Foot Rail.
- H Side Tables, 3 ft. by 1 ft. 3 in. or 3 ft. by 2 ft. 3 in.
- HA Undershelves.
- J Undershelf for conveyor trough.





An Electronic Millisecond Timer

By S. S. West, M.B.E.,* and L. C. Bentley*

IN recent years the need for measuring short time intervals has become increasingly important. In particular the urgency of development work during the war years made it essential that simple equipment should be available for the rapid timing of many mechanical and electro-mechanical operations. For example, camera shutters required to be timed accurately, and conventional methods hitherto employed were time wasting. It is very useful in connexion with such applications to be able to measure time intervals down to 1 millisecond. Such short time intervals are best measured by employing electronic equipment and the particular instrument described here exploits electronic circuits in a manner which ensures accurate results.

The instrument was designed in the development department of Cinema-Television, Ltd., and initially its specific purpose was to time camera shutter operations. Many other applications have been found for it, however, and for this reason it is felt that a description of the circuit arrangement and some of the more obvious applications of this instrument will be useful to many engineers who are concerned with the accurate measurement of short time intervals.

Figs. 1 and 2 above depict the actual instrument in its commercial form, and various adaptor units have been designed to permit the scope of the instrument to be increased.

The instrument is designed primarily to measure short time intervals in the range from 1/2000 sec. to 1/10 sec. with an accuracy of ± 2 per cent. The circuit comprises an electronic trigger arrangement which can be operated either by a photo-cell or from an external source, or if desired by a combination of the two. When the trigger circuit is operated a condenser commences to charge at a constant rate and ceases to do so when the trigger circuit returns to its former position. The voltage attained by the condenser is measured by a valve voltmeter, whose indicating dial is calibrated directly in milliseconds. Three ranges are provided, 0-5, 0-25, and 0-100 milliseconds. In addition extra ranges can be provided up to one second by the attachment of an external multiplier.

The accuracy of the instrument depends almost entirely on the stability of the standard condenser, which is charged during the time that the trigger circuit is "on," and on the calibrating resistance. This matter is dealt with later in greater detail. The circuit arrangement is such that normal mains voltage variations and ageing of valves does not affect the accuracy to any appreciable extent. The theoretical circuit diagram is given by the Fig. 3 and the following describes its principle of operation.

Light falling on the photo-cell will produce a current flow through the resistance R_3. This current flow is in such a direction that a flash of light will produce a negative voltage pulse on the grid of the valve V_1. The shape of this voltage pulse will be approximately the same as the intensity time characteristic of the light flash and would, for example, be rectangular if the start and finish of the flash were instantaneous. More usually, of course, the start and finish will not be abrupt, but there will be a fairly smooth transition from dark to light, and from light to dark. In many cases the duration of the transition periods will be appreciable compared with the total time. In order, therefore, to avoid uncertainty of measurement it is necessary to arrange that the trigger action which controls the charging of the condenser shall be adjustable to operate at definite values of light, that is, the operation of the trigger circuit should be initiated when the light value crosses well defined boundaries. The actual trigger consists of the valves V_1 and V_2—circuit diagram Fig. 3. The operation of this section of the circuit is as follows; the valves V_1 and V_2 have a common cathode resistance R_5, which acts as a coupling between the valves. V_1 is arranged so that normally it is carrying current and the circuit constants are so chosen that the cathode of V_2 is held sufficiently positive with respect to the grid of V_2 to prevent it from passing

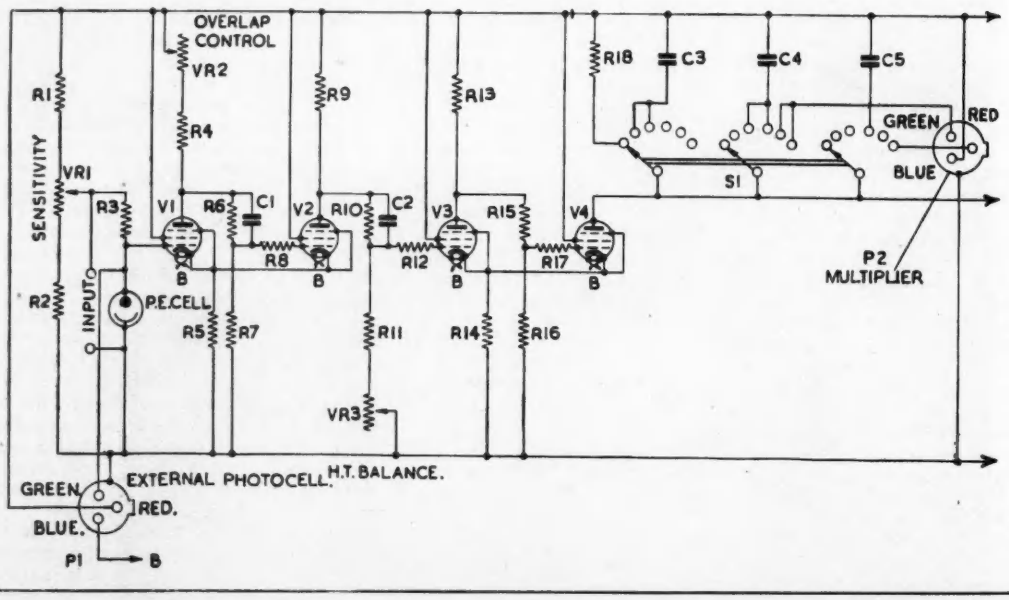
* Cinema-Television, Ltd.

current. When the grid of V_1 is made negative, the current in V_1 is reduced, thus the voltage drop across R_5 is also reduced so that the cathode of V_2 is made less positive with respect to its grid and V_2 is able to commence taking current. When V_2 commences to take current the increased voltage drop occurring across the resistance R_5 will make the cathode of the valve V_1 more positive, therefore the anode of this valve will also become more positive and as the anode of valve V_1 is connected via an R.C. network to the grid of V_2 the current in V_2 will be increased. This effect is a cumulative one. It is apparent that when both valves are in operation the circuit is unstable, but will be stable when either of the valves is biased beyond cut-off. The small coupling condenser C_1 performs an important function in the circuit; at high frequencies it is virtually a short circuit and thus provides a maximum coupling between the anode circuit of V_1 and the grid of V_2. The coupling resistance R_4 in series with VR_2 is relatively high in value, and thus a small mutual conductance in V_2 is sufficient to produce instability. As has been seen above, when this point is reached the system changes over abruptly to the condition when V_2 is taking current and V_1 is cut off. This "tick over" occurs in a small fraction of a microsecond and the time constant of the condenser C_1, with its associated resistances, is such that the potential difference across C_1 cannot change appreciably during the "tick over." The positive voltage applied to the grid of V_2 is therefore determined by the interruption of the current flow in the resistance R_4 and VR_2. During the next microsecond or so following the "tick over" there is time for the potential across C_1 to fall. The potential on the grid of V_2 is then determined entirely by the D.C. potential divider R_6, R_7, R_4 and VR_2. The circuit constants are such that this potential at the grid of V_2 is sufficiently positive to ensure that the valve continues to take such current through R_5 as will ensure that V_1 is biased slightly beyond cut-off. Since the valve V_1 is biased slightly beyond "cut-off" it will be obvious that any further negative excursion of its grid potential beyond the critical potential can have no effect. If the grid potential is raised however, *i.e.*, made more positive, the operation described above will take place in a reverse direction. That is to say, the valve V_1 attains the requisite mutual conductance to cause the circuit to become unstable, whereupon the valve V_2 is cut off and V_1 carries its normal current. There is inevitably backlash or overlap in the operation of this electronic switch circuit. It is, however, much less than might be expected. The factors controlling this "backlash" are as follows:

The change of anode current in V_1 resulting from the tick-over produces a voltage change on the control grid of V_2 via the network comprising the components, R_6, R_7 and C_1 (the resistance R_5 is included only to avoid a possibility of parasitic oscillations). This voltage at the grid of V_2 is not steady due to the presence of C_1, but in a very short time interval falls expotentially to a permanent value, determined by the D.C. potential divider formed by the resistances R_6 and R_7.

In order that the new conditions established by the "tick over" should be stable, the permanent value of voltage at the grid of V_2 must be at least sufficient to hold the normally inoperative valve just beyond cut off, otherwise the inoperative valve could again come into operation, in which case the circuit would behave as a multivibrator.

Assuming the permanent voltage at the grid of the inoperative valve is only slightly in excess of that required for "cut off," then under these conditions a small change at the grid of V_1 will result in the circuit ticking over, that is to say, the backlash will be small. In brief, the backlash is the extent to which the inoperative



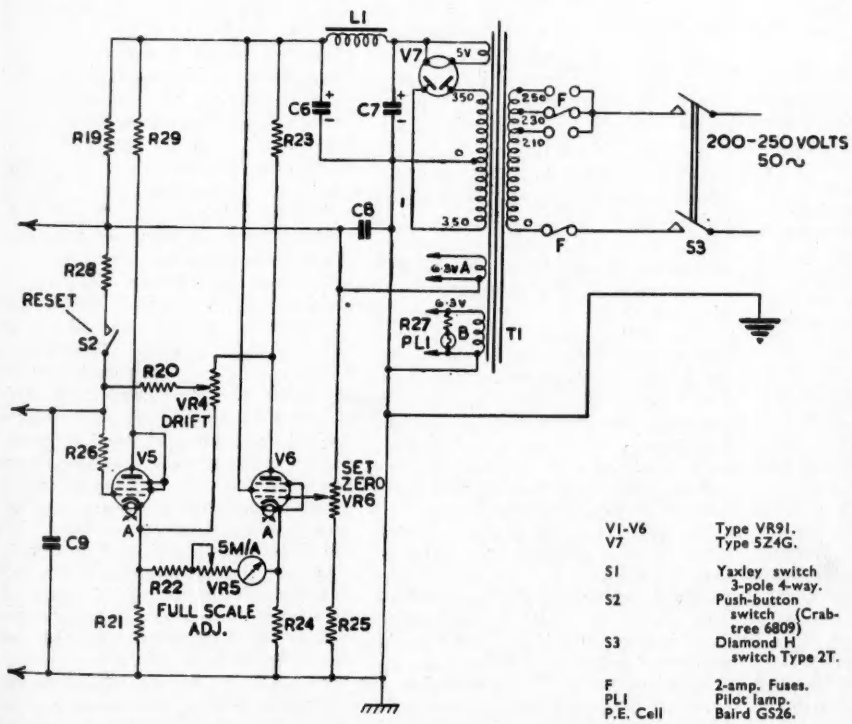
valve is biased beyond its cut-off point and is determined by the extent to which the permanent change of voltage across R_4 and VR_2 is in excess of the minimum required to produce the two stable conditions of equilibrium. In order that this backlash shall be adjustable the resistance VR_2 is made variable. In practice, adjustment to this variable resistance is rarely necessary, except when the valves are changed.

Reference to the circuit diagram shows that the load resistance R_3 of the photocell is supplied via the potentiometer VR_1. It is thus possible to set to a predetermined value the voltage change in R_3 necessary to cause the grid of valve V_1 to reach the critical potential for tick over. The photocell current is proportional to the light faling on it and the circuit can by this means be set to operate at a predetermined light value. It will be apparent that more light will be required to bring the grid potential down to the tick over point when the adjustment of VR_1 is such that its slider is in the position which provides the maximum positive potential to the end of resistance R_3. The range of adjustment of VR_1 is made sufficient to permit the tick over point to be reached without there being any light on the photocell. Such an adjustment, of course, is not a normal working position, but it is useful for purposes of making adjustments to the calibration.

Considering now the effect of illuminating the photocell, it will be apparent that the current through the cell will change and this current change will provide a signal at the grid of V_1 which carries this valve to the critical point required for tick over of the trigger circuit. In referring to the operation of the trigger circuit it was shown that tick over will not take place until the current in the valve V_3 has attained a certain finite value. Since this small current in V_3 occurs before the tick over it is not possible to place the standard condenser directly in the anode circuit and a further pair of valves, V_3 and V_4, are employed as a D.C. coupled limiting amplifier which operates in a similar manner to the circuit comprising valves V_1 and V_2.

Reference to the circuit will show that the voltage change across R_9 is applied to this limiting amplifier and it will be apparent that since this voltage change is a large one no problems of backlash in the second circuit (valves V_3 and V_4) are involved. The inclusion of the condenser C_3, connecting the anode of valve 2 to the grid of valve 3, ensures that the large voltage change occurring across R_9 is transmitted to the valve V_3. In brief, the circuit comprising the valves V_3 and V_4 provides a square wave charging pulse for the standard condensers and removes the possibility of error due to the small current in the valve V_3.

Considering the operation of the valves V_1, V_2, V_3 and V_4, it will be seen that these valves are operative in pairs, that is, either valves V_1 and V_2, or valves V_3 and V_4 are "on," this will be seen from the foregoing



V1-V6	Type VR91.
V7	Type 5Z4G.
S1	Yaxley switch 3-pole 4-way.
S2	Push-button switch (Crabtree 6809)
S3	Diamond H switch Type 2T.
F	2-amp. Fuses.
PL1	Pilot lamp.
P.E. Cell	Baird GS26.

Component Values

R_1	200 K.	1 W.
R_2	75 K.	1 W.
R_3	4 Meg.	1 W.
R_4	2 K.	1 W.
R_5	10 K.	2 W.
R_6	200 K.	1 W.
R_7	100 K.	1 W.
R_8	100 Ω	½ W.
R_9	10 K.	1 W.
R_{10}	200 K.	1 W.
R_{11}	75 K.	1 W.
R_{12}	100 Ω	½ W.
R_{13}	10 K.	2 W.
R_{14}	8 K.	2 W.
R_{15}	200 K.	1 W.
R_{16}	100 K.	1 W.
R_{17}	100 Ω	½ W.
R_{18}	5 K.	5 W ±1% wirewound.
R_{19}	9 K.	5 W.
R_{20}	500 Meg.	1 W.
R_{21}	25 K.	4 W.
R_{22}	5 K.	1 W.
R_{23}	20K.	2 W.
R_{24}	100 K.	1 W.
R_{25}	500 K.	1 W.
R_{26}	100 Ω	½ W.
R_{27}	10 Ω	1 W.
R_{27}	10 Ω	1 W. wirewound.
R_{28}	100 Ω	½ W.
R_{29}	100 Ω	½ W.
C_1	20μμF.	(Ceramic).
C_2	20μμF.	±1%.
C_3	1μF.	±1%.
C_4	4μF.	±1%.
C_5	15μF.	±1%.
C_6	8μF.	Electrolytic.
C_7	8μF.	Electrolytic.
C_8	5μF.	Tubular.
VR1	50 K.	Potentiometer.
VR2	5K.	Potentiometer.
VR3	50 K.	Potentiometer.
VR4	250 K.	Potentiometer.
VR5	2 K.	Potentiometer.
VR6	5 K.	Potentiometer.

Fig. 3. Circuit diagram of the Millisecond Timer.

to be the case with the light "off" or light "on." It is desirable that the total H.T. current should be constant to avoid any change in H.T. supply voltage. To ensure this is so, the sum of the currents in the valves V_1 and V_2, when operative, should be equal to the sum of the currents in the valves V_3 and V_4 when they are operative. A pre-set variable resistance (VR_3) is included in the circuit in order that the operative current of V_3 can be set to satisfy these conditions.

Use is made of the constant current output characteristic at the anode of valve V_4 in order to provide a constant charging current. This is possible by reason of the fact that when the valve V_4 is operative, the valve V_3 is cut off so that any further negative excursions on its grid have no effect. The grid potential of valve V_4 is then determined by the potential divider R_{12}, R_{13} and R_{16}.

The resistance R_{14} in the cathode of valve V_4 is of relatively high value so that the cathode current is almost independent of the valve characteristic and is only dependent on the voltage of the H.T. supply. Thus the valve V_4 passes a constant current which charges the standard condensers C_3, C_4 and C_5, depending upon the position of the switch S_2, for a time determined by the duration of the illumination on the photocell. The resulting voltage change across the condenser will be proportional to the duration of the pulse. In order to secure absolute, rather than relative, values it is necessary to know the charging current, the capacity and the voltage change. The current can be determined by passing it through a calibrating resistance and measuring the voltage drop across this resistance. The absolute measurement then only requires a knowledge of the value of the calibrating resistance, the capacity value and a voltage ratio.

It is convenient to secure calibration in this manner and reference to the circuit diagram shows that for one position of the switch S_1 the anode current of valve V_4 may be passed through the calibrating resistance R_{15}. In its other positions it will be seen that the switch S_1 connects in circuit the standard condensers. A push button switch S_2 permits the condenser to be discharged after taking a measurement.

The valves V_5 and V_6 with the components in their cathode circuits form a simple D.C. valve voltmeter for comparing the voltage developed by the current pulse flowing into the standard condenser with the voltage produced across the standard resistance by the steady current. The readings are given by a milliammeter which, with an adjustable series resistance R_{21}, VR_5, is bridged across the cathode of valves V_5 and V_6. The operation is as follows:

When the grid of valve V_5 goes negative, the current in this valve is reduced and the current in valve V_6 increased. In order to make use of the best part of each valve characteristic, the current in valve V_5 is arranged to be initially higher than the current in valve V_6. This is achieved by the use of dissimilar cathode resistances. Due to the initial difference in current the grid of valve V_6 requires a small negative bias relative to the grid of valve V_5. This is provided by the variable resistance VR_6, which is used as a "zero adjuster" for the meter. The meter circuit and the cathode resistances are all high compared with the cathode impedance of the valve, so that curvature of valve characteristic is effectively eliminated and a linear scale obtained on the milliammeter. Hence the only calibrations required are for the zero and full scale points.

To check the full scale point the switch S_1 is placed in a position which connects into circuit the calibrating resistance R_{18}. The valve V_4 is then arranged to pass current either by adjusting the variable resistance VR_1 or, alternatively, the photocell can be illuminated.

The milliammeter is brought to full scale by adjustment of the variable resistance VR_5 and calibration is then complete. With the values shown in the circuit diagram for the calibrating resistance R and standard condensers C_3, C_4 and C_5, the milliammeter (0-5 mA.) reads milliseconds in three ranges.

So far it has been assumed that both before and after the pulse of current in valve V_4 has charged the standard condenser, the potential on this condenser will be stationary. This implies that the current in the condenser must be exactly zero, except when valve V_4 is operative, a state of perfection which cannot be attained in practice. Several possible sources of leakage current exist, such as valves, valve-holders, switches, etc., of which the valve is the least controllable. The effect of this stray current is to produce a slow drift in the potential across the condenser and hence a slow drift in the readings of the indicating milliammeter. As this might be a source of annoyance to the operator, or even a source of inaccuracy to a slow operator, it has been considered desirable to introduce a degree of correction. The requisite correction is secured as follows:

The stray current in the valve V_4 is balanced by a current in the high resistance R_{20}, which is connected between the anode of valve V_4 and a potentiometer VR_4. The positive end of VR_4 is arranged to be at high potential and adjustment of this potentiometer will determine the potential difference across resistance R_{20}, and hence the magnitude of the correction.

It is then seen that during the charging of the condenser one end of resistance R_{20} falls in potential. In order to maintain the correction current sensibly constant, the other end of resistance R_{20} should preferably fall in potential to the same extent so as to maintain a constant potential difference across resistance R_{20}. As the grid potential of valve V_5 falls, the current in the milliammeter circuit increases and the anode current of valve V_6 increases, thus increasing the volt drop across the anode resistance R_{22}. Thus there is a fall of potential on the anode of valve V_6 and the value of resistance R_{22} is such that this fall of potential is approximately the same as the fall on the grid of valve V_5. The cathode of valve V_5 also follows the fall of potential on the grid. The variable resistance VR_4 is connected between the anode of valve V_6 and the cathode of valve V_5, so that all points on the variable resistance VR_4 fall in potential to approximately the same extent as the grid of valve V_5, and a sensibly constant potential difference is maintained across resistance R_{20}. Thus the drift may be adjusted to zero by means of the variable resistance VR_4 and the adjustment will be satisfactory for both the initial zero condition and the final condition when the condenser has become charged.

A variety of time measurements can be made with the instrument, for example, camera shutters can be tested.

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Telephone Relays

and their use in Electronic Circuits

Part 2.—Relay Circuits

by A. A. CHUBB, A.M.I.E.E.

IT is now proposed to describe a few simple relay circuits showing the potentialities of these devices. Designers of telephone circuits employ a number of small well-tried circuit elements in building the very intricate operational networks characteristic of this art, and certain of these useful in electronics are shown in the Figs. 12-17. Fig. 12 illustrates four ways of operating a relay by means of rectifiers from an A.C. supply. Arrangement 12(a) is suitable for mains voltage working. It gives quick operation, somewhat slow release owing to the slugging effect of the rectifier, and uses the minimum size of rectifier. For example, a 5,000 ohm major relay requires a 20,000 ohm series resistor and a H18/8/1 rectifier in parallel for operation from a 230 V alternating supply. Such a relay fitted with mains contacts could be used for remotely switching on a transmitter of, say, 1 KW total mains consumption.

Arrangement 12(b) is used for operating a relay from a low-voltage supply. Both half-waves are used, but succeeding half-waves pass through alternate halves of the relay which has two separate equal windings, the two fluxes being in the same direction. The relay is quick operating but slow to release. An example would be the operation of a relay having a 50 + 50 ohm coil, from a 12 V A.C. source with a rectifier code D18/1/1.

Fig. 12(c) shows an arrangement for medium voltage operation, having a quicker release characteristic time than the preceding two arrangements. The relay receives half-wave current pulses for operation, and the rectifier must withstand the full mains potential. The condenser acts to smooth the current through the relay to some degree. If, however, the circuit is broken, say, between the relay and the rectifier, to release the relay, the energy in the magnetic circuit is transferred rapidly in known manner to the condenser, which then discharges through the relay reversing the current through the coil and releasing the armature.

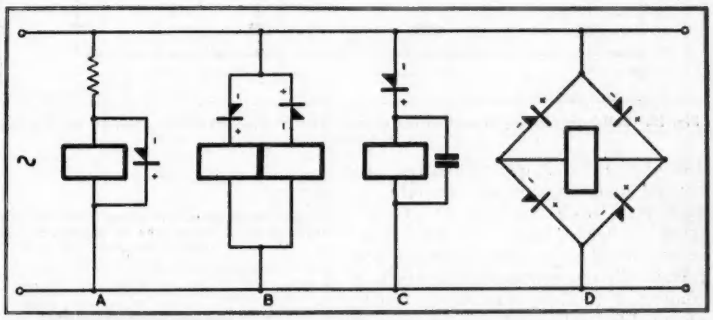


Fig. 12. Rectifier relay circuits for operating from A.C. : (a) Suitable for mains voltage working, (b) Two-coil relay on low voltage, (c) Medium voltage circuit with quicker release than (a) or (b), (d) Best arrangement for limited current from low voltage source.

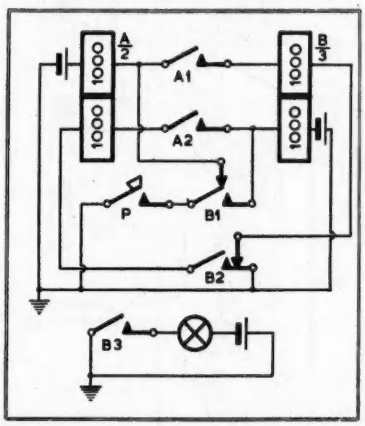


Fig. 13. Connexion of relays to give "on" and "off" with successive movements of push-button.

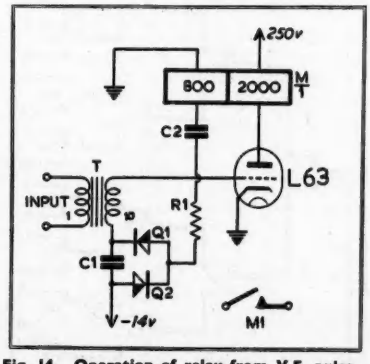


Fig. 14. Operation of relay from V.F. pulse, using rectified reaction.

Fig. 12(d) gives the best arrangement when limited current is obtainable from a relatively low voltage source. All the rectified current passes through the full winding of the relay so that maximum sensitivity is obtained. The rectifier, however, contains twice as many plates for equivalent source voltage as that shown for Fig. 12(b).

Fig. 13 shows a method of switching on some piece of apparatus when a push-button is momentarily depressed, and switching off at the next depression. It consists of two relays, A and B, both having two coils. On first closure of the push-button P relay A operates via its top coil and closes its contacts. When the button is released, relay B operates with its top coil in series with relay A, and its contact B1 prepares to release the two relays later. B2 causes a holding current to flow in both the bottom coils of the relays, and disconnects the two top coils, and B3 closes the work circuit required. On the next closure of the push-button the lower coil of relay A is short-circuited and the relay releases, but relay B remains operated via its lower coil. When the button is opened relay B releases and the circuit restores to the condition shown.

Fig. 14 is a circuit used for operating a relay on receipt of a V.F. pulse, and uses the principle of rectified reaction shown in British Patent

* The General Electric Co., Coventry Works.

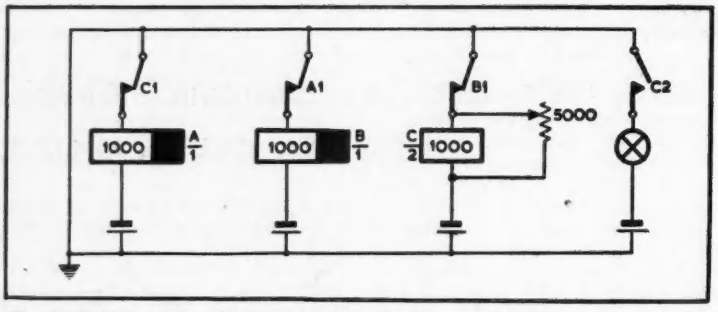
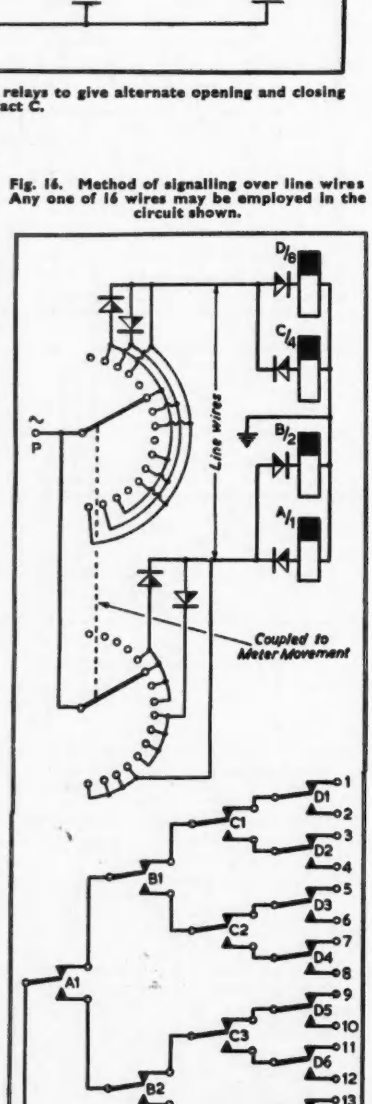


Fig. 15. Self-interrupting circuit, using three relays to give alternate opening and closing of contact C.

No. 385974. It is quite sensitive, and can be made to operate the relay at 25 w.p.m. from an input of 250 mV from a 600 Ω line. This input is connected to a 1 : 10 step-up transformer T, the secondary of which is connected to the grid-cathode circuit of an L63 valve. A cut-off bias of −14 V is applied to the grid, for example, from a potentiometer, and the anode is taken to a 250 V supply via one coil of the relay M. This relay is thus normally unoperated. On arrival of a signal, the first positive half-wave increases the anode current to an operating value and sends a positive pulse, by induction in the second coil of the relay, to the grid circuit via the rectifiers Q_1 and Q_2. This charges condenser C_1 positively and increases the anode current, and the positive potential is maintained on the grid by the back-resistance of the rectifiers during the succeeding negative half-cycle. The relay thus remains operated during application of signal to the input. On cessation of the signal the condenser discharges through the rectifiers, the time constant of the circuit being chosen so as to give the relay a release time as nearly as possible equal to the operate time. The sensitivity can, of course, be increased by the use of a plain amplifier stage preceding the relay operating valve.

Fig. 15 is an expansion of the self-interrupter or trembler-bell circuit. It consists of three relays, two of which are slow-release and one is in parallel with a variable shunt which gives a variable release time. This circuit, when energised by application of current, causes alternate opening and closing of contact C_2, with flickering of the lamp connected to it, at a rate determined by the characteristics of the relays. Although definite and cyclic, the operation of the chain is not entirely obvious since at any instant one relay is energised and operated, one is de-energised but still operated and one is released. Assuming that the chain has been running for some time, and that relay A has just released, then B operates immediately afterwards. This de-energises relay C which releases after a time determined by its shunt resistance. On release of C, A re-operates at once, de-energising B. After the release time of B, its contact re-operates C at once, contact C_1 de-energising A. After the release time of this relay has elapsed A_1 re-operates relay B, and the cycle continues. The closure time of the work contact C_2 is thus release of A + operate of B + release of C − operate of C. By a suitable choice of relay times almost any impulse ratio and time can be obtained. With the arrangement shown a close : open ratio of C_2 from approximately 1 : 1 to 2 : 1 can be obtained, with a speed range of 1 to 12 closures per second, the higher speeds necessitating the use of relays without copper slugs.

Fig. 16. Method of signalling over line wires Any one of 16 wires may be employed in the circuit shown.



A number of methods of transmitting a multiplicity of signals over line wires exist, mostly of the kind involving complex voice-frequency signalling or impulse generation and counting. Fig. 16 shows a method of intimating 1 of 4 things over one wire with earth return, or 1 of 16 things over two wires. In the figure the two coupled switch arms may be on any one of the contacts 1-16, positioned for example by a meter pointer, and it is required to send a message indicative of this position to a distant point. As shown, the wipers apply + ve or − ve halves of an A.C. supply, or the full wave, or nothing, to a line. At the far end thereof the kind of wave employed is sorted out by relays and rectifiers, so that for each wire the relay combinations operable are (1) none, (2) one relay, (3) the other relay, (4) both relays. These relays are provided with interconnected contacts, such that if one wire is used, any required one of four wires is marked. If two wires are employed, any one of 4^2 wires can be marked. This is the circuit shown in the figure. It is, of course, assumed that A.C. of suitable frequency and amplitude can be sent over the line wires, though if these wires are hired from the Post Office, this may not be possible in view of the strict limitations imposed on A.C. transmission. The 16 "output"

wires are numbered in the order in which an earth potential is applied to them by sequential movement and positioning of the originating wipers. The principle can be expanded to three or more wires so that 4^3 or 4^4 signals may be sent provided sufficient relays are employed. In the figure, application of alternating potential to lead P would operate relays D and B, an earth being applied by the contacts of these relays to lead 6. This indicates the contact on which the originating instrument is standing, the indication being given by lamp signalling or similar means.

Finally, Fig. 17 shows a simple form of remote control circuit for a transmitter and receiver operated in Simplex manner, the receiver and transmitter being located at the best point for transmission and being controlled from a point situated up to ten miles away. Such an arrangement is often required in V.H.F. link or area working where the transmitter must be located at as high an altitude as possible, and the control point is in a town. The receiver performance is also likely to benefit by location near the transmitter, not only because of the aerial elevation, but because it is likely to be away from the main sources of man-made interference which are most prevalent in a city.

The device consists, at the control point, of a microphone and amplifier, loudspeaker and amplifier, H.T. supply and 50 V signalling supply, details of these being omitted for clarity. The input of the loudspeaker amplifier and the output of the microphone amplifier are connected in parallel to a 600 ohm matching resistance and are isolated from the line wires by the transformer T1, of 1 : 1 ratio. The secondary of T1 is split, a V.F. connexion being made by a condenser. At the transmitter point a further transformer T2 connects the line wires to the receiver output and transmitter input. The resistance potentiometer shown enables the line impedance to be matched by 600 ohms, and the receiver output by 2 ohms, the transmitter input transformer presenting an impedance which is high compared with these values.

In operation the "ON" key is closed when the apparatus is to be brought into use. In addition, the control point amplifiers, H.T. supply and 50 V supply are also switched on. The valve filaments warm up, H.T. is supplied via B2 to the speaker amplifier and a smoothed direct current flows via relay A, winding of T1, line L1, winding of T2 and relay C to earth return. Relays A and C operate.

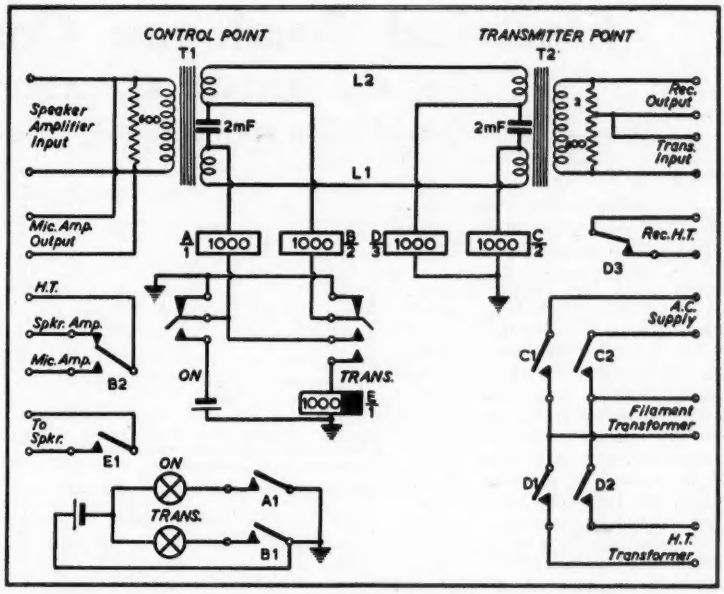


Fig. 17. Circuit for controlling transmitter and receiver from distant point.

A1 lights the "ON" lamp indicating that the required operation has been performed.

C1 and C2 close a mains circuit to the filaments of the transmitter and receiver, and to the H.T. supply of the latter via D3.

After the filament warming-up time is complete, signals entering the receiver are passed over the line wires in loop, and are emitted from the loudspeaker at the control point. When the operator wishes to transmit, the switch "TRANS" is closed. This causes a second line current to flow in relay B, T1, L2, T2 and relay D to earth return; relays B, D and E operate. As the currents in the transformer coils are equal and opposite, no permanent core magnetisation results.

B1 lights the "TRANS" lamp telling the operator that the microphone is live.

B2 disconnects H.T. from the speaker amplifier and connects it to the microphone amplifier.

D3 disconnects H.T. from the receiver.

D1 and D2 connect mains to the transmitter H.T. transformer, energising the transmitter. An aerial switching relay may also be operated by relay D if required.

E1 applies a short circuit to the loudspeaker.

The operator can now transmit any required message, at the end of which the "TRANS" switch is opened. Relays B and D reverse their previous operations, and after all the switching is completed relay E releases, removing the short circuit from the loudspeaker so that switching is substantially clickless.

It is hoped that the few foregoing examples of the application of relays to electronic circuits will be of interest and use to designers entering this field without any preparatory knowledge of the methods employed in telephony.

References

"Relays in Automatic Telephony," Palmer (Pitman).
"Electric Relays," Rosslyn (Newnes).
"Design of Relays for Automatic Telephone Equipment Circuits," Barker, *P.O.E.E. Journal*, April, 1933.
"Relay Timing," Turney, *I.E.E. Journal*, April 1928.
"Sensitive Relays," Jupe, *Wireless World*, August, 1943.
"The Micro-gap Switch," Thornton, *I.E.E. Journal*, vol. 80.
"Relays in Valve anode circuits," George, *Electronics*, August, 1937.
"Relay Contact Materials," *Electrical Times*, June 16th, 1941.
Engineering Supplement, Siemens Magazine, September, 1940. December, 1941.

Electrical Analogue Computing

By D. J. MYNALL, B.Sc., A.M.I.E.E.*

Part 2—Electro-Mechanical Multiplication, Division and Integration

Mixed Quantities

A NATURAL next step is to consider multiplication. In a restricted sense, this has already been illustrated. In Fig. 3, for example, there is a multiplication of the voltage handled by any particular transformer into its turns ratio, and both the additive and multiplicative properties of this circuit have been exploited in practice. Reference 3 provides an illustration of this. However, in general, the variation of transformer turns ratio does not provide a convenient method of introducing a really "live" variable.

The most directly useful products which occur naturally in linear circuits involve quantities of different kinds, such as the product of current into impedance or voltage into admittance. Coupling this with the observation that the most direct way of controlling an impedance or admittance with precision is by mechanical means, one is led to consider electro-mechanical multiplication.

For example, the simple linear resistance potentiometer shown in Fig. 8 is effectively an electro-mechanical multiplier. The output voltage is proportional to the product of a voltage and a mechanical displacement.

Continued products may be formed by cascading potentiometers as shown in Fig. 9, provided that the loading of one potentiometer on another is kept to negligible proportions. When extensive cascading is called for, in order to deal with a considerable number of input variables, it may be impracticable to satisfy the loading condition to the required order of accuracy. One way of overcoming this difficulty is to introduce precision buffer amplifiers between the stages, but a rather neater method is to use a series of negative feedback amplifiers, as shown in Fig. 10, in which linear variable resistor elements are used as the feedback elements, the overall gain of each stage being proportional to the amount of resistance included in the feedback element and, therefore, to the mechanical displacement of the slider from the zero resistance position. Each stage reverses the sign of the electrical quantity applied to it. When significant, this can be corrected by a stage of fixed gain introduced for the purpose.

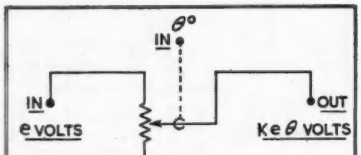


Fig. 8. Simple electro-mechanical multiplier : mixed mechanical and electrical input quantities.

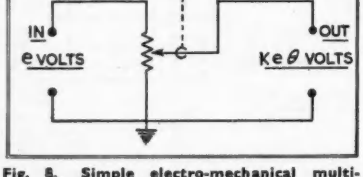


Fig. 9. Extension of the simple multiplier to deal with three input variables (mixed quantities).

Another approach to the problem is to employ a series of attenuators of the bridged-T type, as shown in Fig. 11. This avoids the use of amplifiers, but calls for more complex variable elements. Each stage of this type of multiplier employs two ganged, non-linear, variable resistors so designed that the current delivered to a chosen load resistance is a fraction of the input current directly proportional to the mechanical displacement of the resistor sliders. Further, the design is such that the input resistance of each stage, when it is working into the chosen load, is constant and equal to the load. Thus, all stages are correctly loaded by the following stages provided that the chosen load is applied to the last stage, and there is no fundamental limit to the number of stages which may be used. Matching on the input side is employed to keep the output resistance constant.

The method of design of suitable attenuators may be found in Reference 9 or 10.

In the schemes which have just been described, mechanical and electrical quantities are mixed, and it is relevant, at this point, briefly to consider means and methods for putting the variables on a consistent basis, either all-electrical or all-mechanical. The device which allows this to be done is known as an electro-mechanical servo system.

* Precision Circuits Section, Electronics Engineering Department, British Thomson-Houston Co., Ltd.

Fig. 10. Electro-mechanical multiplication by means of cascaded feedback voltage amplifiers.

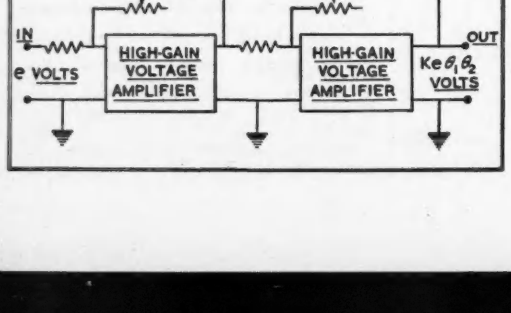
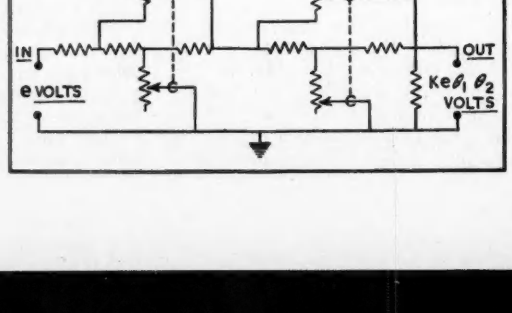


Fig. 11. Electro-mechanical multiplication by means of cascaded bridged-T attenuators.



Electro-Mechanical Servo System

In a characteristic arrangement, a valve circuit, known as the "servo amplifier," controls the rotation of an electric motor. The direction of rotation changes with the sign of the electrical input to the servo amplifier, and the motor will rest only when the input is substantially zero. The motor is coupled mechanically into the system, so that it can influence the electrical conditions, and always tends to change its control input towards zero. The whole system thus seeks a null condition, in which it settles, provided that the system has been correctly stabilised. The gain of the motor control system is made high enough to ensure that the null condition can be determined with precision. The whole system is another example of negative feedback technique, and the precise characteristics of the amplifier and motor are unimportant, provided that the control is powerful enough to give precision and substantially to eliminate the effects of mechanical inertia within the operating frequency range. This simplifying assumption is made in the examples which follow.

A study of the methods which may be employed to stabilise such an arrangement, so that self-oscillation is avoided and the system made to keep itself closely nulled under all conditions of operation is outside the scope of this article, but may be studied, for example, in Reference 11.

Consistent Quantities

Returning to electro-mechanical multiplication systems, Fig. 12 shows how the electrical output from the circuit of Fig. 9 can be converted to a mechanical output. The auxiliary linear potentiometer is adjusted automatically by the servo drive, until the slider voltage is equal to the voltage representing the mechanical product, so that the mechanical displacement of the servo system is proportional to this product. Since the input data is in mechanical form, this makes the system consistent on a mechanical basis.

This method of converting the output quantity to a mechanical basis is, of course, equally applicable to a greater number of stages or to the circuits of Figs. 10 and 11.

On the other hand, all quantities may be converted to a consistent electrical basis by employing a servo system to change each input voltage to a proportional mechanical displacement which is then used to operate the appropriate movement. For example, the application of this principle to the circuit of Fig. 8 results in the circuit of Fig. 13.

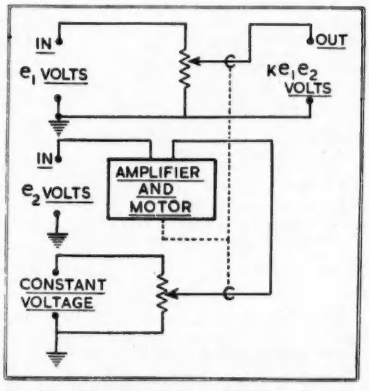


Fig. 13. Use of the servo principle to provide an electro-mechanical multiplier on a consistent electrical basis.

As before, this method may be used with a greater number of stages or other types of circuits.

In the circuits of Figs. 8 to 13, the mechanical variables cannot range through zero, and the bridged-T and feedback amplifier multipliers are essentially restricted in this fashion. It is possible, however, to remove this limitation from the potentiometer circuits by arrangements which are balanced to earth. Fig. 14 is a typical example. It is a direct modification of Fig. 12, in which centre-tapped potentiometers (duplicated where necessary) are substituted for the single-sided potentiometers of the simpler circuit. The earthed centre-taps are not essential, but are helpful in reducing the effects of loading and departures from perfection in the construction of the potentiometers.

Special potentiometers with two sliders operating in mechanical opposition on the same winding may be used to avoid duplication of potentiometers, or, alternatively, a single, centre-tapped potentiometer forming part of a negative feedback amplifier, so that the two halves of the winding take the place of resistors r and R in Fig. 6, may be employed to drive a balanced system from a single-sided input.

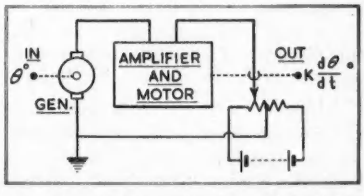


Fig. 15. Electro-mechanical differentiation with respect to time (mechanical basis).

It is perhaps worth noting that when alternating quantities are being handled it is possible to substitute precision inductive potentiometers for the resistive elements shown in the diagram. The advantage to be gained is that these elements are not so much affected by loading of the slider circuits.

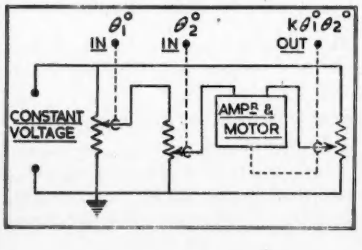


Fig. 12. Use of servo principle to provide an electro-mechanical multiplier on a consistent mechanical basis.

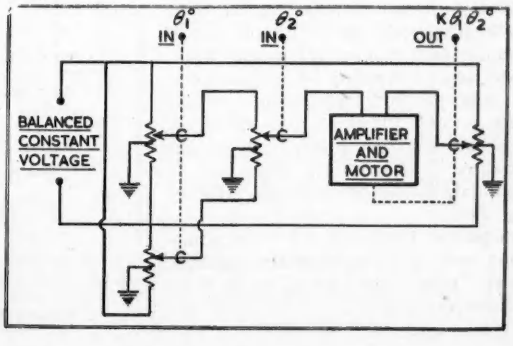


Fig. 14. Example of a consistent electro-mechanical multiplier (mechanical basis) capable of dealing with input and output variables which range through zero.

Electro-Mechanical Division

To complete the basic operations of arithmetic it is necessary to consider the process of division.

The formation of the quotient of two quantities can be achieved by a slight re-arrangement of either of the circuits of Fig. 12 or Fig. 13.

In the first of these examples it is sufficient to interchange the supply leads to the middle and right-hand potentiometers. When this is done the output will be proportional to θ_2/θ_1.

In the second example it is sufficient to interchange the supply leads to the two potentiometers in order to make the output proportional to e_1/e_2.

Checking over either of these modified circuits will reveal that the principle employed is to multiply a quantity into the divisor and to balance it against the dividend by means of the servo amplifier and motor. It follows, from this automatically solved equation, that the servo-adjusted quantity is the desired quotient.

Examples of applications of the multiplying and dividing circuits just discussed can be found in Reference 12.

The feedback amplifier multiplier of Fig. 10 also lends itself to division. If linear variable resistors are substituted for the fixed input resistors in any or all of the stages, it is possible to divide by the variables thus introduced. In fact, by varying both feedback and input elements it is possible to obtain a quotient in which both divisor and dividend are formed from continued products. This can readily be seen by reference to the limiting gain expression for one stage, given in Fig. 6.

Before leaving the subject of division, it may be noted (anticipating a later section) that a variable can be transformed into its reciprocal. Thus, one way of dividing by a quantity is to multiply by its reciprocal. Where the variable elements in a multiplier are already non-linear, as in the bridged-T multiplier, there is, in general, no loss of simplicity involved in designing any desired stage to a reciprocal law, and this transformation and use of multiplying technique may effect an overall economy (Reference 12).

Differentiation and Integration

Electro-mechanical computing also admits of the operations of differentiation and integration, but, before proceeding to describe how these may be dealt with, it is important to make a distinction which is not always clearly understood.

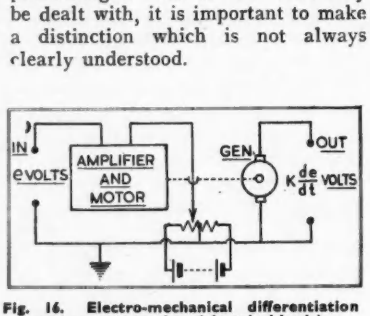


Fig. 16. Electro-mechanical differentiation with respect to time (electrical basis).

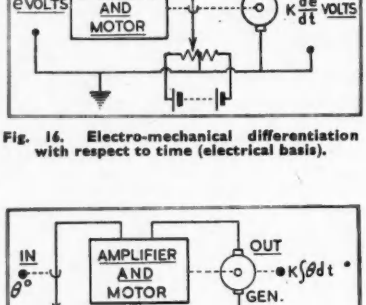


Fig. 17. Electro-mechanical integration with respect to time (mechanical basis).

Fig. 18. Electro-mechanical integration with respect to time (electrical basis).

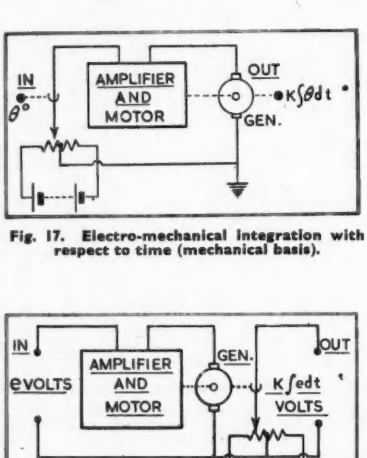


Fig. 6. Addition of input resistance r to Fig. 5 to form feedback amplifier.
Repeated from Part I., page 180.

In the electro-mechanical field, a number of quantities can be found which are connected by a simple differential relationship. In instances of practical importance the differentiation is with respect to time. For example, the voltage produced by a tional to the time rate of change of angular position of the armature tachometer type generator is propor- (speed of rotation). Such an element lends itself to the design of differentiating and integrating units in which time is one of the variables.

In many applications, time can be accepted as an independent variable, but it should be noted that its independence is extreme—there can be no control over it, nor can it be consistent with the other variables.

Units which are on a completely consistent basis (for example, a unit to give a voltage proportional to the rate of variation of another voltage with respect to a third), may be built up from the less general types.

When the context calls for explicit distinction, the writer uses the terms "time differentiator" (or "time integrator") and "consistent differentiator" (or "consistent integrator").

Electro-Mechanical Time Differentiation

Considering first, then, electro-mechanical differentiation with respect to time, Fig. 15 gives an example which is practically self-explanatory, in the light of what has gone before. The D.C. generator has an armature position denoted by θ, and therefore delivers a voltage which is proportional to $d\theta/dt$, assuming a linear speed-voltage characteristic. This voltage is converted to mechanical displacement by a servo system of the same type as in Fig. 12, to make the input and output quantities consistent. The servo potentiometer is shown balanced to earth, to allow rates of change in either direction. Generators with specially accurate characteristics have been developed for this type of service (see, for example, Reference 13).

Fig. 16 is an example in which the input and output quantities are electrical.

Electro-Mechanical Time Integration

A slight change to Fig. 15 gives Fig. 17, which is an integrating unit, with mechanical input and output quantities. This particular arrange-

ment is known as a "Velodyne" (Reference 13).

Fig. 18 is an integrator handling electrical quantities.

It is worthy of note that the units on an electrical basis are not quite as generally useful as those on the angular mechanical basis, since the completely unrestricted range of armature position available when using the circuits of Figs. 15 and 17 has no electrical analogue in Figs. 16 and 18.

The integrating and differentiating circuits just described are not fundamentally restricted to D.C. operation, but if A.C. operation is desired it is clear that the D.C. generator must be replaced by a special A.C. machine having a linear speed-voltage characteristic at constant frequency, as, for example, an induction type machine with constant frequency excitation.

Electro-Mechanical Consistent Differentiation and Integration

Given two quantities of the same kind, x and y, and wishing to form the differential coefficient of one with respect to the other (say, dy/dx), it becomes obvious that this can be done by a combination of units which have already been described when the form of the identity

$$dy/dx \equiv (dy/dt) \div (dx/dt)$$

is examined. In other words, the desired result can be reached by separately forming the time differentials of each input variable and dividing one result by the other.

In a like manner, examination of the form of the identity

$$\int y dx \equiv \int (y.dx/dt)dt$$

shows that a consistent integrator can be built up by using a time differentiator, a multiplier and a time integrator.

This apparently disposes of the problem, but it is important from a practical point of view to note that, while the terminal quantities of the assembled unit must be consistent, there is no compulsion to keep the links between the sub-units on the same basis. Starting with an assembly of units such as those described previously, it is generally possible to find and eliminate certain unnecessary conversions, thus saving in complexity and bulk and gaining in overall accuracy of performance.

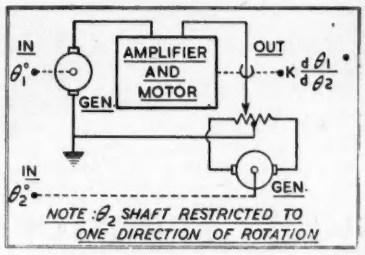


Fig. 19. Electro-mechanical differentiation of a mechanical variable (angular displacement) with respect to another of the same type.

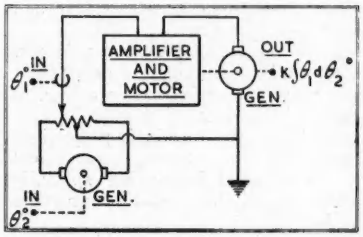


Fig. 20. Electro-mechanical integration of a mechanical variable (angular displacement) with respect to another of the same type.

For example, Fig. 19 shows a consistent differentiator on a mechanical basis, in which the internal links between the time differentiators and the divider are electrical. An integrator of the same type is shown in Fig. 20. Other types of consistent units can be worked out in a similar fashion.

REFERENCES

[9] McElroy, P. K.: "Designing Resistive Attenuating Networks," *Proc. I.R.E.*, Mat., 1935.

[10] Terman, F. E.: "Radio Engineers' Handbook," McGraw-Hill Book Company, Inc.

[11] Whiteley, A. L.: "Theory of Servo Systems, with Particular Reference to Stabilization," *Journal I.E.E., Part II*, Aug., 1946.

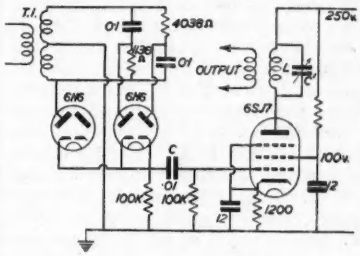
[12] Shannon, W.: "Electronic Computers," *Electronics*, Aug., 1946.

[13] Williams, F. C., and Uttley, A.: "The Velodyne," *Journal I.E.E., Vol. 93, Part IIIA, No. 1*, 1946.

(To be continued)

A Frequency Tripling Circuit

In the February, 1947, issue of *Tele-Tech* (formerly the Telecommunications Section of *Electronic Industries*), a simple frequency tripling circuit is described by W. C. Brown, of the U.S. Signal Corps. It is pointed out that the circuit is simple to operate and construct, and that there is no trace of the fundamental in the output. On the other hand, it is extremely selective, has a low efficiency, and requires high quality components in three or four places.



The principle of the device is a half-wave polyphase rectifier followed by a high-Q wave-reshaping circuit. As shown by Rissik,* the output of a polyphase rectifier system can be considered as a D.C. voltage on which is superimposed a ripple consisting of a number of harmonics of the fundamental, each of differing frequency and amplitude. The D.C. component is removed in the circuit shown by the capacitor C, and the filtering of the harmonic is accomplished by the tank circuit of which the band-width at the half-power points does not exceed 10 per cent. of the desired harmonic frequency.

A similar arrangement can be used for quintupling, using voltages 72° apart in phase. The phase shifting in each case is obtained from simple RC networks such that $\phi = 2.\tan^{-1}X_c/R$.

The values shown are for an input frequency of 620 c/s.

* *Electrician*, August 11, 1939.

—*Tele-Tech*, Feb. 1947, p. 79.

Fig. 2. Fluid filled toroidal transformer (component parts).

Toroidal Transformers

By A. LANGLEY MORRIS, M.I.E.E.

THE almost universal use of rectangular stampings for small transformer cores has tended to obscure the possibilities of the toroidal form of construction. This was justifiable while transformer applications were in many cases limited to domestic radio sets. We have now to consider aircraft radio and radar sets which have to operate under far more onerous conditions. Transformers in such equipments warrant more attention than has been hitherto given them.

Modern aircraft must operate in every kind of climate, and the transitions from tropical conditions to temperate, or even frigid, are quite rapid. To eliminate climatic deterioration of the windings it has been found necessary to seal transformers in some form of container. Thus this pan-climatic requirement tends to make transformers larger and heavier in direct contradiction to aircraft requirements of smaller and lighter components.

When the conventional transformer is sealed in a rectangular or circular can, there is considerable wastage of space. This wastage is usually augmented by the terminal projections inside the can. Some improvement can be effected by having specially shaped cans, but entails expensive tooling.

Fig. 1 illustrates a toroidal transformer in a cylindrical container. It may be seen that there is little wastage of space and that even the central hole of the toroid has been utilised by the projections of the terminal stems. While individual terminals are satisfactory, the construction is particularly adapted to the circular multi-lead terminal, and it is relatively easy to make the soldered connexions between the windings and the terminal pins. Those who have had experience in attempting to eliminate the space wasted by terminal projections, without making difficult the soldering of the leads, will appreciate the great advantage of the toroidal form.

Economy of volume is very desirable when the transformer is fluid-filled. It limits the amount of expansion required by the fluid under operating conditions and reduces costs when expensive fluids such as silicones are used. The toroidal transformer again is the ideal form for using the circular corrugated metal bellows as the container, the metal bellows thus providing compensation for fluid expansion. Fig. 2 shows the component parts of a fluid-filled toroidal transformer.

A major criticism against the toroidal transformer is that of winding, for which special machines are required. A number of these winding machines were described in a recent article (*Electronic Engineering*, July, 1946). They have been used by the telephone industry for a number of years, because the toroidal winding

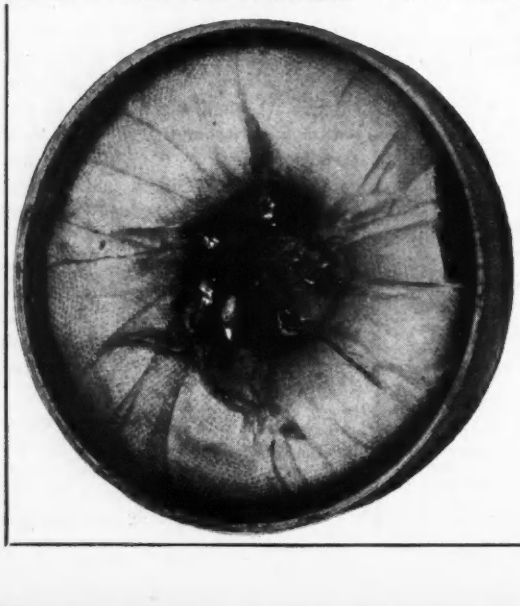
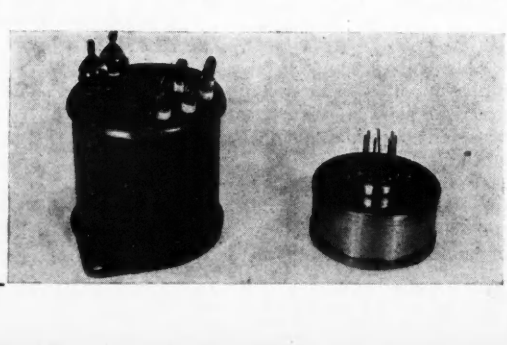


Fig. 1 (*left*). Toroidal transformer in sealed container. (side view).

Fig. 3. Sealed 1500 cycle transformers: (*left*) conventional pattern, (*right*) toroidal pattern.



causes less inductive interference than the bobbin winding.

It still might be thought, however, that the space saving characteristics of the toroidal construction are not sufficient to offset the production difficulties of winding. Consideration should therefore be given to another advantage of the toroid, namely, core simplicity.

Power frequencies other than 50 c/s. are finding increasing applications. For airborne equipments, there is much to be said for frequencies up to 3,000; 400 c/s. and 1,600 c/s. being well established. High frequency transformers demand thin laminations if full use is to be made of the magnetic material, and the high flux densities which are now possible make it imperative to have good interlaminae insulation, which must be thin in relation to the lamination thickness, otherwise the iron space factor becomes poor. It has been found that oxide coating upon nickel iron stampings is not a reliable insulator at high flux densities, thus the problem of coating large numbers of thin stampings arises. There also is the production problem of assembling stacks of thin laminations (.004 in. thick for 1,600 cycle working).

Strip-wound toroidal cores avoid these difficulties as well as not requiring special stamping tools. The

Fig. 4. C type cores.

strip, which can be as thin as the electrical conditions require, can be coated with insulation by a continuous process of which the cataphoresis process looks most promising. The core can then be annealed and finally varnished.

High frequency transformers require relatively few turns in contrast to 50-cycle transformers, for example, a 6.3 volt filament winding on a ⅜ in. square core requires 14 turns for 1,600-cycle working against 290 for the same core section at 50 c/s., and thus the winding problem is eased.

The picture Fig. 3 shows two 1,600 c/s. transformers of 30 V.A. rating at 35° C. rise. The toroidal transformer weighs 4½ oz. against 7 oz. for the conventional transformer.

The toroid is therefore most attractive at the higher frequencies, but developments in silicon iron core material may make it advantageous to use toroidal cores for 50-cycle working.

By cold-rolling silicon iron a grain oriented material with enhanced magnetic properties is obtained. Low losses and high permeabilities are possible provided the direction of the flux follows the preferred grain direction. This precludes the material being used in the form of stampings.

In America a core construction known as the C pattern (Fig. 4) has been produced. Hipersil (a grain orientated silicon iron) in a tape form is wound into a "rectangular" toroid. The core is then cut so that bobbin windings can be used. The cutting of the core is not an easy process and there is danger of spreading of the laminations at the joint unless the cementing of the laminations is good. Again the core has a tendency to open out resulting in poor butting of the joints. A toroidal core avoids these dangers and the expenses of cutting. Therefore under certain conditions it may be almost as economical.

It must not be thought that the toroidal transformer provides a unique solution to transformer problems. It is not attractive for high voltage rectifier supplies owing to the large number of turns and the insulation difficulties. For filament supplies, especially in the multi-winding variety, it looks ideal.

Index to Vol. XVII

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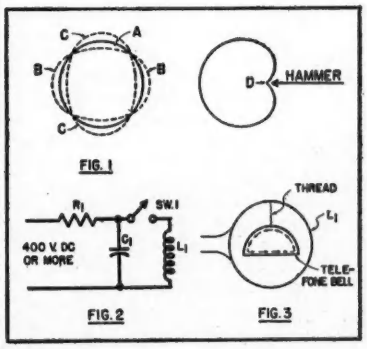
Ringing a Bell at its Fundamental Mode

IN the May issue of *Audio Engineering*, formerly *Radio*, S. Y. WHITE describes a method of ringing a bell at its fundamental mode of oscillation by means of a condenser discharge through a coil surrounding the bell.

It is pointed out that there is no method of squeezing the bell from the circular shape of Fig. 1A into the oval of Fig. 1B, as the impact of a hammer produces a dimple as in Fig. 1D. This impact gives rise to extremely complex oscillations.

The circuit of Fig. 2 is used, in which C_1 is 20-100 μF, charged from a D.C. source of 400 V or more through the limiting resistor of 10,000 ohms. The coil L is wound from 50-100 turns of 24 A.W.G. on a former, or can be wound in a bunch and taped up. The switch Sw should preferably be of the mercury type to prevent sticking together of the contacts.

The bell used was of the ordinary door-bell type suspended in the centre of the coil.



On closing the circuit, a current is induced in the side of the bell as shown by the arrows and an equal current is induced in the opposite side. The repulsion between the current loops cause the bell to be forced into the oval shape of Fig. 1C, and it oscillates at the fundamental note.

It may be necessary to insert a series resistance in the coil circuit to ensure that the circuit is critically damped, as an oscillatory discharge will weaken the tone.

—*Audio Engineering*, May 1947, p.17.

Teflon — *An Improved Plastic for R.F. Use*

By W. S. PENN, B.Sc.

MANUFACTURERS are already aware of the value of polythene as a high frequency dielectric. In fact, the dielectric constants (2.3) and power factors (0.0001) over a wide frequency band, seem as low as it is possible to go for these constants. However, a new plastic, closely related to polythene has been developed, possessing a dielectric constant of 2.0. It is capable of being used between frequencies of 50 c/s. and 3,000 Mc/s. The chemical name for this new dielectric is polytetrafluoroethylene and it is marketed by E. I. du Pont de Nemours, Inc., of America, under the trade name "Teflon."

In view of its excellent dielectric characteristics it has been proposed for many purposes, including radar equipment and colour television, and it is likely to be of inestimable value to these industries.

Composition and Preparation

It is well known that polythene (trade name Alkathene) is prepared by the polymerisation of ethylene ($CH_2=CH_2$) to long chain molecules at high temperatures and pressures. In a similar manner Teflon is prepared by the high temperature and pressure polymerisation of the corresponding fluoro compound ($CF_2=CF_2$).

In other words, the hydrogen atoms of polythene are replaced by fluorine atoms. This introduces marked chemical and electrical differences. One important consequence of this (possibly from the point of view of use in aircraft) is the increase of the specific gravity from 0.92 to 2.2.

Appearance

Thin sections of Teflon are transparent or translucent. With increasing thickness, however, it becomes white like polythene, which it very much resembles. The plastic also seems very waxy and sometimes is greyish in appearance.

Like polythene, there is sometimes some discolorisation, which can be overcome in the following way: The plastic should be cut up to present as large a surface area as possible. It should then be heated in an oxidising atmosphere at between 50° C. and 500° C., and if this treatment is continued for somewhat more than half an hour, the dark colour will be removed.

Electrical Properties

Some electrical properties of Teflon are summarised in Table 1 and for the sake of convenience those of polythene are also given.

The plastic has very low loss characteristics, which make it ideally suitable for high frequency applications. The wide range of frequencies has already been mentioned. The dielectric constant should be noted in particular and the curve of dielectric constant against frequency is virtually flat up to 3,000 Mc/s. Thus the plastic is very promising for colour television with its exacting demands and like applications.

Compounding and Forms Available

Although the plastic may be compounded on open mills, it is very tough and more difficult than polythene. Fillers have been mixed with the plastic, but colours have not so far been used. It is probable that for electrical applications it will be necessary to incorporate stabilisers (*e.g.*, lead silicate) to absorb any polar fluorine containing gases which could be liberated at elevated temperatures.

In addition to extrusion, chips, rods, tubes, sheets and films are available for further processing.

For making articles such as coil forms, there are two possible methods. In very simple instances, compression moulding has been possible. However, machining is the simplest and ordinary wood working equipment may be readily used. Tools should be kept sharp.

Chemical Properties

The excellent electrical properties are accompanied by a phenomenal chemical resistance. Tests carried out so far indicate that the only materials which dissolve it are the molten alkali metals. The plastic is not affected by boiling aqua regia and sulphuric acid, hydrofluoric acid, fuming nictric acid and strong alkalis.

The plastic resists organic solvents, and its water absorption is nil, this being particularly important from the electrical point of view.

Heat Resistant and Mechanical Properties

The heat resistance of the plastic is excellent. It may be employed over the range 100° F. to 480° F., which is better than that of polythene. There is no true melting point, but the tensile strength drops considerably at about 750° F. On decomposition, through the action of heat, the plastic gives mainly tetrafluoroethylene. Even at lower temperatures, however, small quantities of miscellaneous gases are given off.

The mechanical properties of Teflon are fairly satisfactory and certainly better than those of polythene. This is illustrated in Table 2.

The higher tensile strength and the improved heat resistance should be noted. The specific gravity is also increased substantially, but this should not be a drawback in the electrical industry.

Uses

The uses for a plastic with such excellent electrical properties are obvious. These are mainly where really high frequencies are used and good electrical properties are needed in the presence of corrosive materials. A dielectric for coaxial cables in colour television has been one proposal, and other applications which come to mind are for radar and submarine cables. The unique electrical, chemical and mechanical properties promise many future uses for this plastic.

TABLE 1.
Electrical Properties of Polytetrafluoroethylene.

		Polythene	Teflon
Dielectric Constant	60 c/s	0.0001	0.0001
	10^6 c/s	0.0002	0.0002
	10^9 c/s	0.0003	0.0002
Power Factor	60 c/s	2.3	2.0
	10^6 c/s	2.3	2.0
	10^9 c/s	2.4	2.0
Dielectric Constant—			
0.075 in. thick		1000	—
0.080 in. thick		—	480
5-12 mil. thick		—	1000-2000
Volume Resistivity ohms./cm.³		10^{15}-10^{17}	10^{16}

TABLE 2.
Mechanical Properties of Teflon and Polythene.

	Polythene	Fluoro Compound
Specific gravity	0.92	2.2
Tensile strength (77° F.) lb./sq. in.	1900	2000-4500
Impact strength I. (77° F.) ft. lb./in.	>3.0	4.0
Yield temperature °F.	200	>320
Brittleness temperature °F.	−4 to −94	<−100
Water absorption per cent.	0.01	Nil
Compressive strength lb./sq. in. (77° F.)	1700	2000

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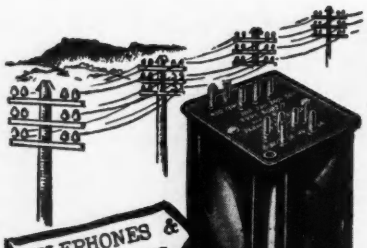

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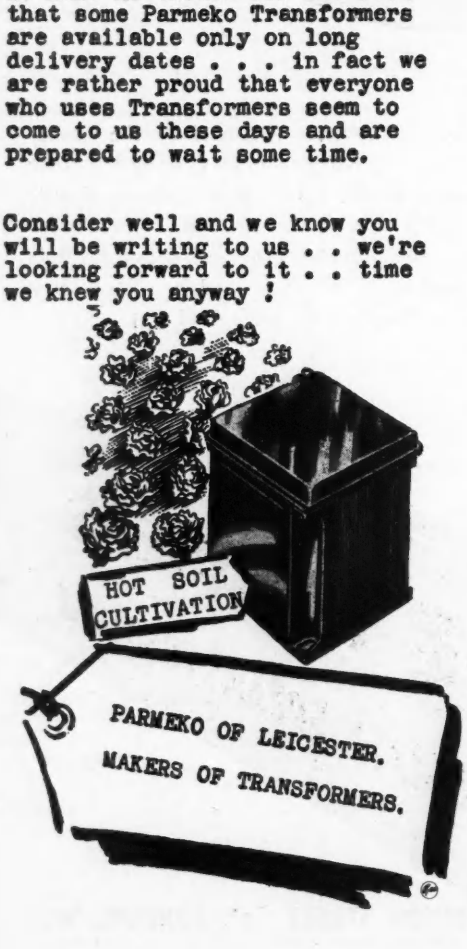

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DA 138/46

A Portable Two Channel Amplifier and Ink Recorder

By W. GREY WALTER, M.A., Sc.D. and ALAN A. BROOKS*

THIS equipment was designed for electro-physiological purposes, but has been found suitable also for other applications.

The main requirements influencing the design of the amplifier were:

1. Voltage amplification of the order of 10^7.
2. Frequency response of amplifier "flat" from 0.5 c/s. to 10 kc/s.
3. Power output to drive robust ink-recorders.
4. Economy of space, weight, and power consumption.
5. Good discrimination against unwanted inputs such as 50 c/s. mains ripple.
6. Quick recovery from "blocking" by large transients greater than 100 μV.
7. Noise level as near "basic" as possible.

Several of these requirements are clearly incompatible or at least imply compromise for their fulfilment. Thus size, weight and consumption can be reduced only at the expense of other features. Again an overall time constant long enough to preserve gain at less than 1 c/s. is inseparable from some degree of blocking when the coupling condensers are charged by surges.

After considerable experiment with the well-known permutations of the basic circuits, that shown in Fig. 1 was adopted.

There are two identical channels supplied from a common battery and power-pack. Each channel may be considered as consisting of two separate amplifiers, and, in fact, the preamplifiers and power amplifiers are housed in separate carrying cases (Fig. 2).

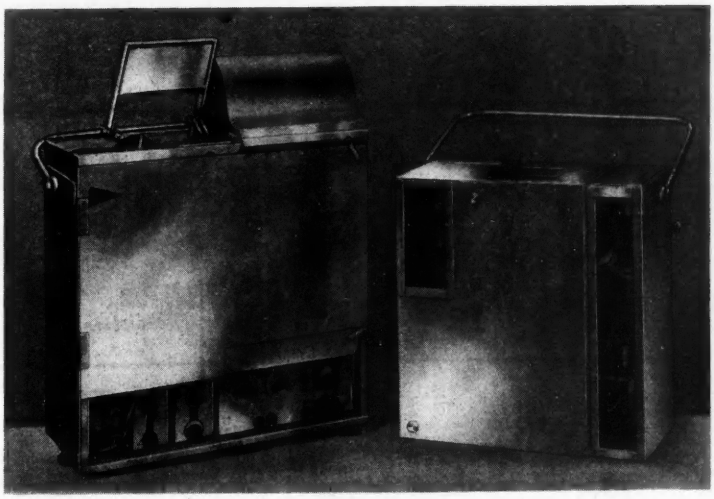


Fig. 2. General view of amplifier and recorder (left) showing projection mirror and accessory cupboard (extreme right).

Preamplifiers

The preamplifiers are R-C coupled and high tension is supplied from a common battery. The main points of interest are:

1. The calibrating circuit follows standard practice in providing for calibration through the signal source (or patient when the equipment is used for biological or medical purposes). A small current set by R_2 and read from the meter is passed through a low resistance R_3, the voltage drop across which is seen by the input grids when the input leads are shorted or connected to the signal source. The DPDT switch allows calibration of both channels or their separation when used independently.

2. The Mazda V312 input valves which maintain a reasonable noise level over a long life without variation. Amplfiier noise in the frequency band below 20 c/s. seems to contain components not predicted by the usual expressions. This noise is sometimes referred to as "raggle" since it is characteristically irregular and physiologically inaudible. It originates in the first valves and is worse in high-slope valves, though individual valves of this class may be free from it. Mr. A. H. Beck, in a private communication, has suggested that this noise component may be due to periodic or random changes in grid surface characteristics, possibly as a result of contamination of the grid wires by barium or strontium from the cathode. Variations due to this effect would not be subject to space charge smoothing as would those attributed to "flicker." Such fluctuations would also be greater in high-slope valves due to the proximity of grid and cathode, and would also vary considerably from one valve to another.

3. The high value of the common cathode resistor R_4 and the compensating positive grid bias obtained from the battery by earthing its centre tap. This provides discrimination against (grid-grid)-earth potential changes of the order of 100: 1. Greater discrimination can be obtained with more elaborate circuits, but these are not usually effective over a wide range of input grid-grid resistance. The cathode current of V_1 plus V_2 is 1.5 mA, so that about 75 volts is required to bring the grids back to their working points. This circuit is a simple derivative of the Tönnies-Matthews circuit analysed by Saunders. (ELECTRONIC ENGINEERING, May, 1942, p. 760.)

4. The anode resistors for this stage include a wirewound 50,000-ohm potentiometer for balancing the push-pull output.

5. The second stage valves must have a high slope in order to compensate for the rather low gain of the first stage (× 15). HF pentodes (Mullard type EF.50 or Mazda SP.42 or V.888) are suitable. The all-glass bases tend to work loose, particularly in portable equipment, and a firm clamp is necessary.

6. The first and second stage valves are heated by the same transformer

* Burden Neurological Institute, Bristol.

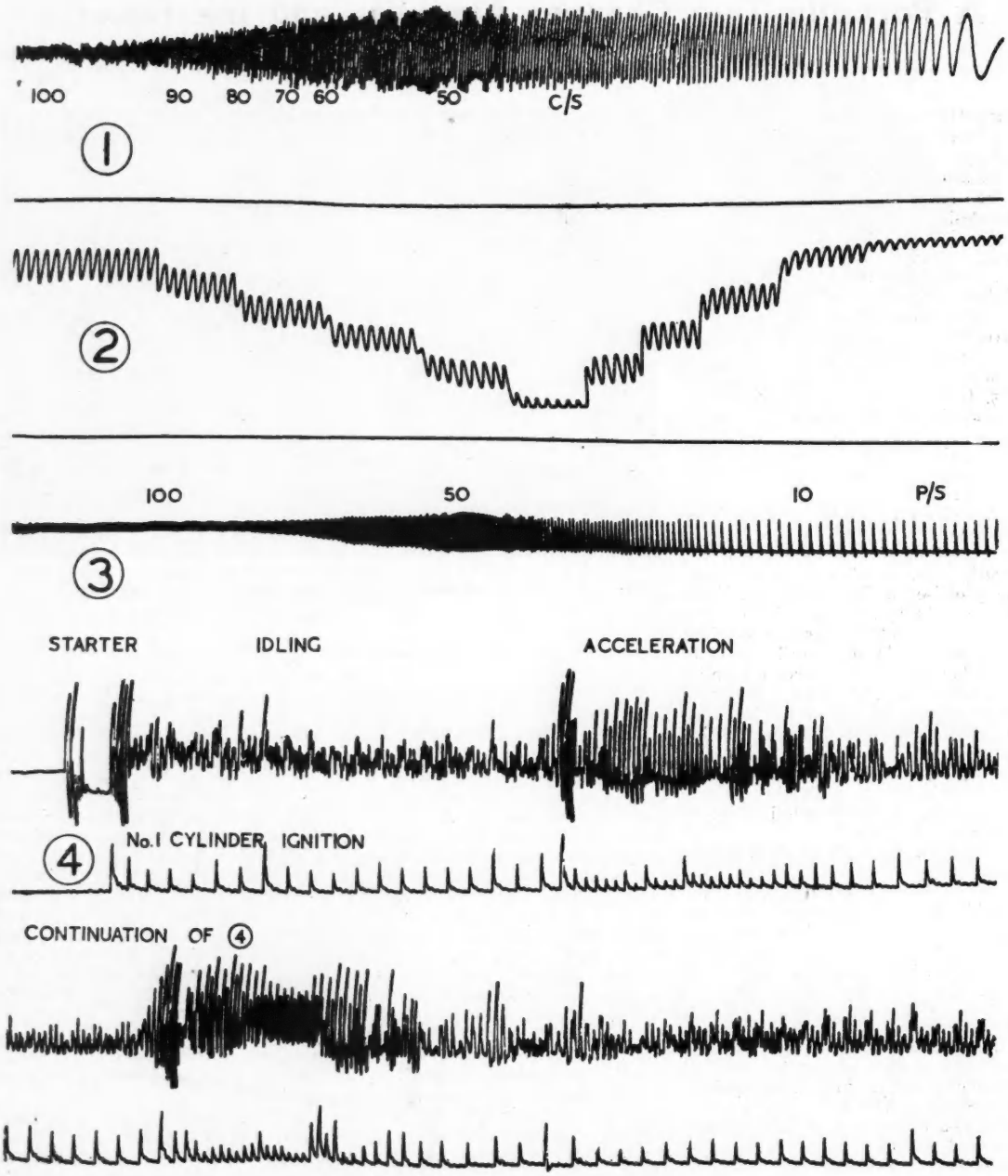


Fig. 5.

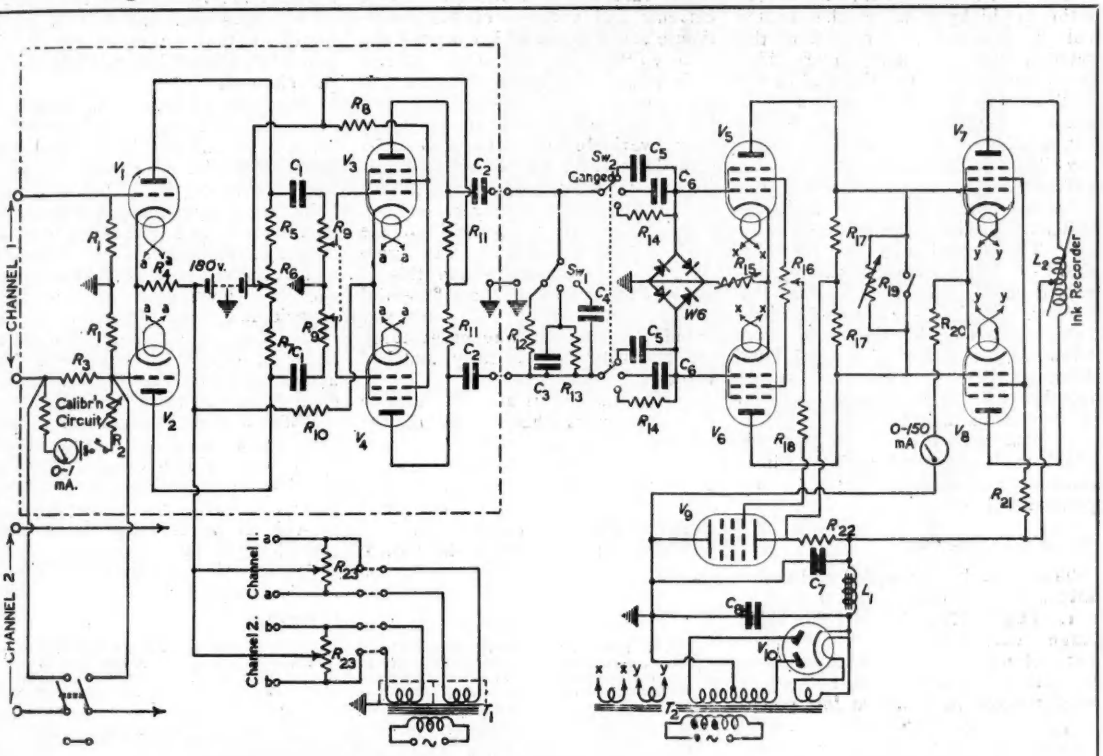
(1) Frequency response of the whole equipment to a signal varied in frequency from 100 to 1 c/s. A 50-cycle signal is superimposed so as to permit calibration by beats.

(2) A demonstration of the linearity of the DC amplifier and recorder over a wide range, a 5 mv. 10 c/s. signal being superimposed on a stepped voltage change covering a span of 30 millivolts.

(3) The response of the whole equipment to brief transients from a photo-cell illuminated by an electronic stroboscope, showing the maintenance of response up to 70 flashes per second.

(4) The use of both channels in an engineering problem, to record engine vibration and cylinder ignition. An irregularity of the ignition system is seen to coincide with transient vibrations of the motor.

Fig. 1.—CIRCUIT DIAGRAM OF PORTABLE E.E.G. EQUIPMENT



RESISTORS.

		watts.
R_1	1 M Ω carbon	½
R_2*	10,000 wirewound pot	½-1
R_3	0.2 Ω	
R_4	50,000 carbon H.S.	5
R_5	25,000 „ „	5
R_6	50,000 wirewound pot	5
R_7	25,000 carbon H.S.	5
R_8	250,000 „ „	1
R_9	1 M Ω ganged pot	½
R_{10}	150,000 carbon H.S.	5
R_{11}	250,000 „ „	5
R_{12}	500,000 „ „	½
R_{13}	1M Ω „ „	½
R_{14}	25,000 „ „	½
R_{15}	1,000 wirewound pot	5
R_{16}	25,000 „ „	5
R_{17}	250,000 carbon H.S.	2
R_{18}	50,000 „ „	1
R_{19}	1 M Ω stepped attenuator	2
R_{20}	500-750 wirewound adjustable ...	10
R_{21}	4,000 wirewound	5
R_{22}	1,500 „	5
R_{23}	50 wirewound pot	2

CONDENSERS.

C_1	4 μF	350 V.	wkg paper
C_2	2	350	„
C_3	.03	250	tubular
C_4	.05	250	„
C_5	.1	250	„
C_6	.5	250	„
C_7	8	750	paper
C_8	4	750	„

Condensers C_1 and C_2 should be of the best possible quality.

VALVES.

V_1, V_2 Mazda V.312
V_3, V_4 } Mazda SP.42 or
V_5, V_6 } Mullard EF.50
V_7, V_8 Mazda Pen. 45
V_9 Marconi Stabilovolt 280/40 or 2 S.130 stabilisers.
V_{10} Osram UU.8 or equivalent.

TRANSFORMERS.

T_1 Primary 0-200-250
Secondary 4v. 3A. two windings, screened.
T_2 Primary as before
Secondary 450-0-450 250 mA.

L_1 15 H. 250 mA.
L_2 Pen coil : 30,000 turns of No. 40 enamelled. 6,000 Ω

*Additional resistances in meter circuit may be required, depending on range and battery voltages.

winding. Both stages are underheated since the gain : hum-level ratio is highest when the heater voltage is about 50 per cent. of the rated value. The humdinger slider is returned to the negative end of the H.T. battery. This reduces to a great extent the residual hum due to the A.C. heating of the first stage.

7. The screens of the second stage valves of one channel have a preset dropping resistance to facilitate matching of the two channels.

8. The second stage valves also share a large cathode resistor returned to the negative end of the battery. This stage also discriminates against (grid-grid)-earth interference by a factor of several hundred, so that the first two stages together have a discrimination ratio of $> 10{,}000 : 1$.

9. The output is taken through 1 μF condensers and variable time-constant and filter circuits to the power amplifier.

The Power Amplifiers

These are direct coupled and mains driven from a common power pack.

1. The grid leaks for the third stage valves are Westectors in parallel opposition. The function of these rectifiers is to act as resistances of about 0.75 megohms at low potential differences and as greatly reduced resistances when the voltage across them increases. Between 0.1 and 1 volt the curves inflect sharply and at 2 volts the slope resistance is about 50,000 ohms. Thus, when the amplifier is working normally the grid swing at V_8, V_9 is of the order of 10 mV. and the time constant of the coupling is about 1.5 sec. If a much larger surge appears it lowers the time constant to 0.1 sec. or less, so that the charge in the condensers is quickly lost and the amplifier can return promptly to its working condition. Together with the 2 μF condensers and 250,000-ohm anode resistors and high impedance valves of the previous stages, these rectifiers give a time constant of just over 1.5 sec. at working levels of potential change. This is reduced to just one sec. by the presence of the previous R-C coupling, and this is the overall time constant of the whole amplifier since the next coupling is direct. The gain is, therefore, reduced by about 10 per cent. at 0.35 c/s.

2. The common cathode resistors (R_{18}) for the third stage valves are adjustable and are used for setting the operating level of the output power valves by controlling the anode currents and voltages of the penultimate stage, upon which depend the grid voltages of the power valves. This could be done by adjustment of the power stage cathode resistors, but these would have to be heavy duty variable resistors since the cathode current of these stages is 60 mA at least, while that of the penultimate stage is only 1.5 mA.

3. Balancing of the two sides of the push-pull penultimate stage is essential for D.C. operation and this is done by adjustment of the differential screen potentiometer R_{16}. This was found the simplest way of avoiding the necessity for carefully matched valves.

4. The gain controls are variable resistors across the anodes of the penultimate stages.

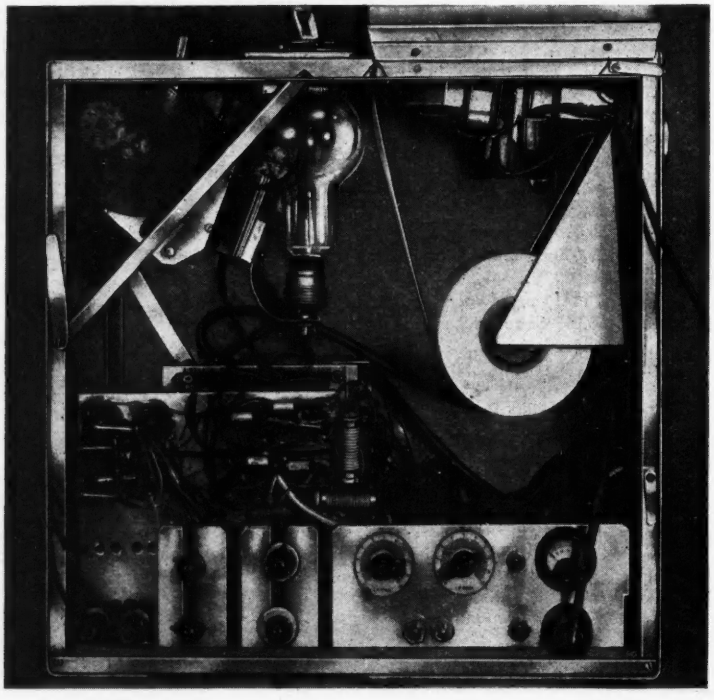
5. The last stage power valves need no grid leaks. The cathode resistor of 1,000 ohms carrying the combined cathode currents of both valves provides the necessary voltage drop to compensate for the positive potential applied to the grids from the preceding anodes.

7. The power pack provides stabilised H.T. voltages for the penultimate stages and unstabilised power for the output stages at 320 V, the power dissipated being about 20 W per channel.

The mains-driven D.C. amplifiers are useful instruments by themselves since a full output is obtained with an input to the penultimate stage of 20 mV grid-to-grid. This is enough gain for many purposes, since most microphones and photo-cells give an output of this order. The absence of R-C. couplings reduces phase distortion to a level determined by stray capacitances and inductances and even these are low since there are no bulky or screened components. The amplification of this section is constant from zero to 20 kc/s.

With the addition of the pre-amplifier a full 8-watt output in two 3,000 ohm. driving coils is given by a grid-grid potential change at the input of 20 μV across 2 megohms. A 200-volt swing is available in these conditions for driving a *CRO* instead of ink recorders, and alternative non-reactive anode loads are provided for this purpose.

Fig. 3. Interior of power amplifier and recorder showing paper roll on the right and the lamp for projecting the trace. Control of paper speed is by the stroboscope disk in the upper left hand corner. The knobs below are (left to right) : R 15, R 16, and, on main panel, R 19. Below R 19 are the muting switch and paper drive motor switch. The switch by the meter changes it over from one channel to the other.



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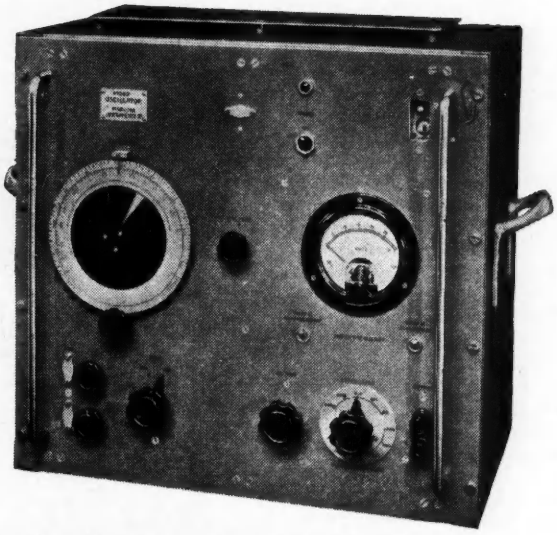

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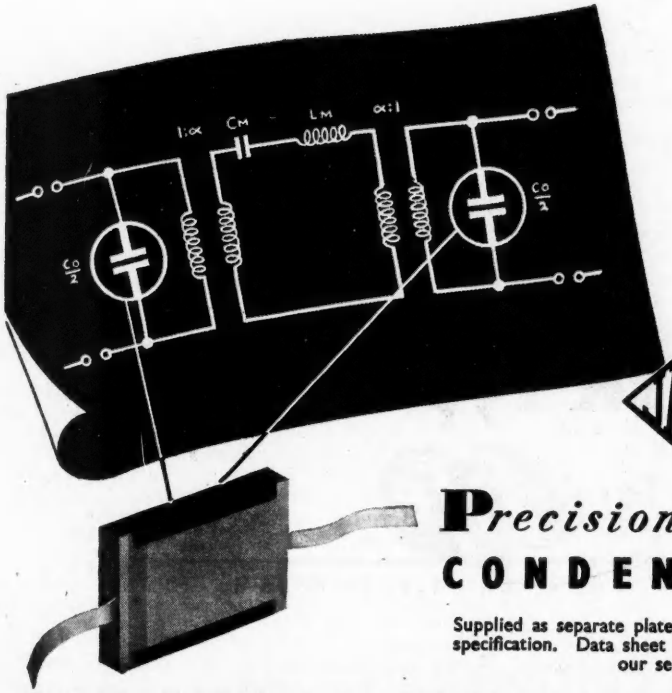

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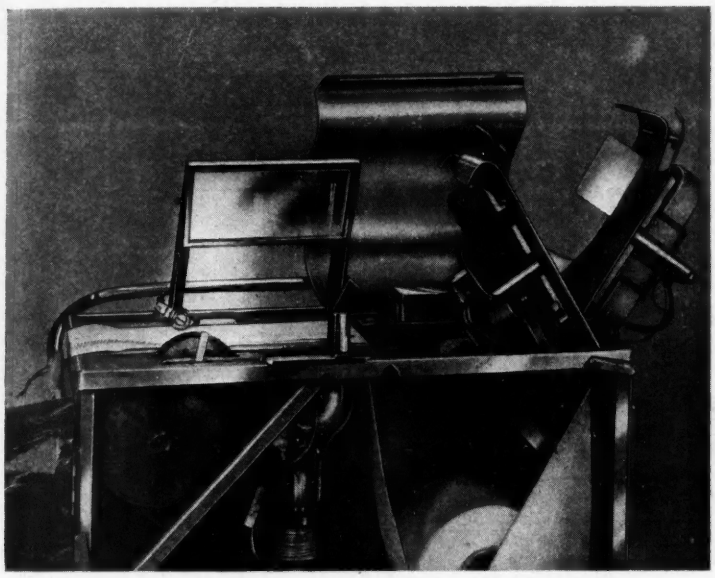


Fig. 4. View of top of recording unit with pens lifted to show arrangement of writer assemblies. For projection of the trace a lens is inserted in the socket which can be seen in the centre of the front bar. The safety inkwell is at the back of the pen units.

Construction

Light weight and accessibility were the main factors influencing the mechanical design of the amplifiers. The two channels are built on the same chassis. The cases have a duralumin angle framework and aluminium panels. The chassis are aluminium and are mounted vertically with wings and channels pressed out to accommodate controls and heavier components. With this arrangement all components and their connexions are immediately accessible without removing the chassis from the case. Hinged doors are provided on three sides of the preamplifier and the whole of the power amplifier is accessible (Fig. 3). A small illuminated Perspex cupboard is built into the preamplifier case to accommodate accessories, tools and spare parts. The single H.T. battery is accommodated in a compartment below the amplifier. The all up weight of the preamplifiers complete with battery and accessories is 35 lb. The power amplifier unit, which contains also paper drive assembly and ink recorders weighs, with an 8 lb. reel of recording paper, 46 lb.

Paper Puller

The paper is pulled by an induction gramophone motor through gears and chain drive. A stroboscope facilitates maintenance of a constant speed. The paper speed is variable from 1 to 3 cm. per sec., stroboscope calibration being given at 1, 1.5, 2 and 3 cm/sec. The final spindle is on ball bearings and engages the paper through a milled friction wheel, with which the paper is kept in contact by a spring-loaded ball-bearing jockey wheel.

Projector

The writing platform is of heat-resisting glass. Below it is a 150-watt lamp and above it a mirror and lens system which is used to project an image of the record as it is taken on a vertical screen (British Patent No. 571321). This feature is valuable for lectures and demonstrations as well as during surgical operations or at any time when signal-source and record must be viewed simultaneously. Conversely, an image of a distant scene can be projected on to the recording paper as in a camera obscura. A changeover switch provides faint illumination from a pilot lamp also below the transparent platform when the record has to be watched in darkness. The switching of the paper-drive motor and the 150-watt bulb are interlocked so that the latter cannot be switched on when the paper is stationary.

Recorders

The design of the ink recorders is based on a model made some years ago by G. Parr. The movements are similar to that known as the "balanced armature" and used at one time for loudspeakers. The principle and layout is indicated in Fig. 6 and the disposition of the instruments on hinged baseplates in Fig. 4. The pen-driving coils are wound on a No. 14 Bakelite bobbin and have 15,000 turns each of No. 40 s.w.g. enamelled copper. The armature is made from transformer laminations made up to 3 mm. thick and measures 12 mm. wide by 75 mm. long. As originally constructed the armature was controlled by a steel torsion spring, but following a suggestion of Mr. P. D. Saw, of Mervyn Sound and Vision, Ltd., these have been replaced with bonded rubber suspensions. (Silentbloc BSR.8.) These have the advantages of being self-damped and extremely robust, but a more important fact is that since the whole spindle rotates it is possible to bolt the pen arm to its end, thus greatly simplifying the layout when two or more recorders can be staggered vertically, and the pens can be brought out alternately at the top and bottom. The last trace of resonance is removed by an R.C. shunt across the driving coils.

The ink feed is from a common non-spill reservoir through soft P.V.C. and 0.5 mm. polythene tube. These substances are quite unaffected by ink and the lightness of the polythene avoids increasing the moment of the pen arm, which is fabricated from a light duralumin channel section. The writing point is a 5-mm. length of No. 18 stainless steel "hypodermic" tube, ground and honed to a dome, and held in the polythene tube by a larger polythene cuff.

The response characteristics of the equipment and some of its uses are indicated in Fig. 5. The first record (1) shows the response to a signal varying in frequency from 100 cycles per sec. down to 1 cycle per sec. The absence of resonance and writing speed are seen to permit recording up to about 75 cycles per sec. and the trace remains clear at paper speeds four or five times greater than that used for the record. The other records are explained in the caption.

Input Valves

The V.312 input valves require the metalising to be connected to earth and not to the cathode, as is normally the case. To do this, the coating is scraped off for about ⅛ in. above the rim of the base and a wire is lightly soldered to the coating above this gap. It may be necessary to select valves for the input stage with the minimum of microphony and internal noise, both of which effects are exaggerated at low frequencies.

In wiring the heaters provision should be made for changing over the wires to find a connexion which gives minimum hum when the amplifier is set up.

Setting-up and Adjusting

In setting up the amplfier it is important that the first stages should be accurately balanced to provide maximum discrimination against unwanted in-phase signals applied to the input terminals. This is done by applying a small A.C. signal (100 mV) between the earth and the two input terminals coupled together and observing the output from the stage by means of a sensitive valve voltmeter or C.R.O. connected across the anodes.

The normal bias of the valves V1 and V2 is 1½ V and this can be measured by a high resistance voltmeter between cathode and earth with R6 set at approximately the centre point of its travel. R4 is then adjusted until the required bias is obtained. The A.C. signal is then applied to the input and R6 altered until the valve voltmeter shows zero.

The balance of the second stage is now checked by transferring the voltmeter to the output of V_3 and V_4 and reducing the input signal to about 1 mV. If the apparent balance point is different from that previously found it indicates lack of matching in the valves V_3 and V_4 or in the resistors of the second stage. Unmatched valves are the most likely source of unbalance and the most satisfactory remedy is careful selection.

Heater Hum

Heater hum can only be detected with the full amplifier in operation, as it should not exceed a few microvolts of equivalent signal. Normally it is removed from the output by adjustment of R23 with the A.C. test input disconnected, but if the hum level is high it indicates either an unsatisfactory input valve or wrong connexion of the heater leads (*see above*).

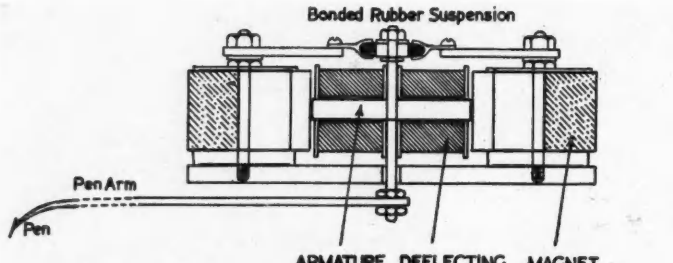


Fig. 6. Diagram illustrating principle and construction of pen unit. With a pen arm 13 cm. long the maximum deflection is 3 cm. peak-peak. The magnet used in the unit is Ticonal Type M. 1229.

Output Stage

The adjustment of the direct coupled output stages is goverened by the anode current required from the output valve. The cathode resistor R20 is first set to develop a voltage equal to the anode voltage of the previous stage plus the required grid bias of the output stage. In the Pen. 45 this bias is approximately 4 V, and with, say, 60 V on the anodes of the previous stage this gives 64 V = 640 ohms at 100 mA total cathode current.

The cathode current having been fixed, the cathode resistor of the previous stage (R15) is then adjusted to produce the required anode voltage (60 V) on V5 and V6.

It is important that these valves should be accurately balanced, since any difference is amplified and reproduced in the output stage. Balance is effected by adjustment of R16 and its attainment is shown by the pen taking up a central position on the paper. The pen should not move when the "muting switch" across R19 is closed.

Filters and Time Constants

In the central position the filter attenuates 50 c/s. by approximately 50 per cent. and is useful in reducing mains interference under exceptionally unfavourable conditions. The third position attenuates 30 c/s. by 50 per cent.

The maximum time constant is about 1.0 sec. with the switch SW2 in the lowest position. In the centre it is 0.25 sec. and in the upper position 0.05 sec., which is still adequate for audio-frequency recording, while eliminating "base-line swing." It is desirable to match the components accurately in both the time constant and filter circuits.

Acknowledgement

The authors wish to express their thanks to the Medical Research Council who defrayed part of the cost of this equipment.

The Physics of Industrial Diathermy—*Part I.*

By A. W. LAY, A.M.I.E.E., F.Inst.P.*

IN manufacturing processes involving the application of heat to industrial materials such as plastics, the thermogenic properties derived from high frequency electric current offer several advantages over the orthodox methods now in vogue.

When heat from an external source is applied to a material, no heat is generated within the boundaries of the body. If the material is a good thermal conductor there will be a low temperature gradient between the boundary of the body and its centre; but if the thermal conductivity of the material is low, such as wood, there will be a steep gradient from the point of application of the heating agency to the centre.

The flow of heat towards the centre of the body is equal to the temperature difference multiplied by the thermal conductivity or diffusivity, which are synonymous terms.

All problems which involve the variable flow of heat depend upon particular solutions of Fourier's fundamental equation.

Mathematical analysis is beyond the scope of this article and will be dealt with elsewhere.

It will be convenient to explain here that high-frequency heating is a popular term for diathermy—a classical term, meaning "through heating." It has been in use for many years by the medical and allied professions, who have been applying its thermogenic properties to the human body as these properties have high therapeutic value by virtue of their uniform heating effect.

The application of these properties to industrial materials such as plastics, is a logical development of this technique, and it would appear that "industrial diathermy," rather than "high-frequency heating," would give the industrial application its exact meaning.

It will be convenient at this stage to consider the elementary physical laws which govern the thermogenic action of the high-frequency energy in producing heat uniformly through plastics, which is the class of material with which we are mostly concerned here.

* Marconi Instruments Ltd.
MS. received May 1946

As is well known, from a practical point of view, a plastic material is one which, in general, lends itself to moulding processes. From a purely scientific point of view a plastic is organic material composed of a large molecule, without regard to any specific use.

Plastics can be broadly covered by two main classifications: (1) thermoplastics, and (2) thermosetting plastics.

The main characteristics which differentiate the two types are that thermoplastics will stand softening and resoftening processes which require the application of heat and mechanical pressure—providing that the temperature of the heating process is not sufficient to cause any chemical decomposition of the material. Hence the term "thermoplastic," which means that the softening and hardening process is reversible. The material softens when heat is applied, and hardens when allowed to cool.

In contrast, thermosetting materials undergo a chemical change under the influence of heat and pressure which converts the material into an infusible, insoluble mass which does not yield formation to further application of heat and pressure. The heating process is irreversible.

According to Polanyi's classification, matter may be divided up into two main classes which are represented by the crystalline and amorphous states.

Plastics are amorphous materials; when they change their form the molecules change places, and an increase in temperature increases their mobility by lowering the viscosity of their environment.

This means that the viscosity of amorphous materials is very dependent on temperature; but the behaviour of materials which have been plasticised by heating is a subject too wide to consider in detail here as it involves the relative state of shear of the molecular layers of the plasticised material.

The main factors which influence the flow of plastic materials are indicated by the equation:—

$$\frac{S}{\mu} = \frac{\pi G}{8} e^{B/RT}$$

where μ is the rate of shear, which is a complex function, S is the external stress causing the material to flow at the shear rate μ, B represents the average value of the molar energy which will restore the molecules to their original position after thermal agitation, T is the absolute temperature, G the modulus of rigidity, and e has the usual significance.

Wax compositions, bitumastic products, natural resins, celluloids, glass-like plastics, vinyl, methacrylic acid derivatives and styrene represent the class of thermoplastics. In this class the basic material is polystyrene, prepared from styrene, which is a derivative of C_6H_6 (or benzene). This is of special interest to radio engineers by virtue of its low loss factor and dielectric constant, and is better known as "Distrene." Phenolic, urea, and casein plastics belong to the thermosetting class.

Mechanism of Heat Generation

The first consideration in the physics of high-frequency heating is that of the mechanism by means of which heat is generated within the plastic itself instead of being conveyed from the outside. This naturally involves the nature of the molecules of which the material is composed.

For our purpose the molecules of plastic materials, can, in general, be described as "polar" and "non-polar." This can be explained without entering into a detailed account of atomic theory by considering molecules as being composed of electrons and nuclei, and that these are in a state of vibration about fixed points in space.

If the centre of the electrical charges on the molecule coincide this is a "non-polar" molecule; but if there is a spacing l between the positive and negative charges then we have a "polar" molecule. (Fig. 1.)

In diathermy, or high-frequency heating, we are mainly concerned with polar substances, as the dielectric constant and loss angle of these are, in general, higher than those which are non-polar; this is because molecular dipoles contribute to the polarisation.

Either type of molecule, that is polar or non-polar, of which dielec-

trics and plastics are composed becomes electrically polarised when under the influence of an electric field.

This polarisation, which is common to both types of molecule, is composed of electronic polarisation, which forms in about 10^{-10} secs., and of atomic polarisation due to the movement of atoms in a molecule. They polarise the material to a nearly constant extent when electric fields below optical frequencies are applied. When considering dielectric materials and plastics, the atomic polarisation may be neglected, as it is small.

In some of the low loss insulating materials, such as polystyrene, the polarisation is mainly electronic.

It must be remembered that, in general, dielectrics must be good insulators and, unlike good conductors in which electrons travel freely, there are very few mobile electrons in insulators. True dielectric action is not then due to free charges in the materials of which the insulator is composed, although a fictitious dielectric constant may appear if there are a few charges in the body which are slightly mobile about a fixed centre, while they are under the influence of an electric field, but which are not free to leave the dielectric.

In a good conductor the charges are mobile and if such a conductor is placed between other charges the force between them is zero, and we have electrical screening; but in true dielectrics the charges are not mobile and therefore their characteristic action is not due to free charges.

Long before the discovery of the atomic model with planetary electrons Maxwell had imagined atomic dipoles and had deduced that in a rapidly alternating field of optical frequencies the atoms would polarise.

In his electromagnetic theory he inferred that the index of refraction γ for colourless transparent bodies was related to the dielectric constant by the equation

$$\gamma^2 = \epsilon \quad \ldots\ldots (1)$$

If, however, the applied frequency coincides with the natural frequency of the electron in its orbit then we have anomalous dispersion.

While Maxwell's explanation of polarisation was nearly correct for many substances, it did not fully explain the theory of polarisation when ϵ has a very high value.

Maxwell's conception means that displacement polarisation is due to the distortion of the orbits in which

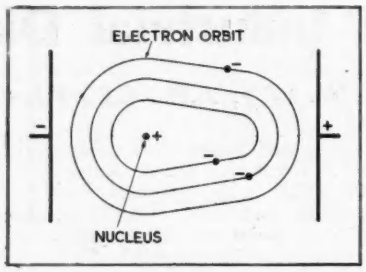


Fig. 1. Diagram of polar molecule in which the centres of positive and negative charges do not coincide.

electrons travel round the positive nucleus when the atoms are under the influence of an electric field.

In a normal neutral atom the system of electron orbits about the nuclei is symmetrical so that at any finite distance from the atom the dielectric fields of the nucleus and swarm of electrons are superimposed and no displacement of charges is noted.

If, however, an electric field is applied the electron orbits are slightly distorted and the effective centres of the nucleus and the electron orbits are no longer symmetrical, but separated by a distance which is mathematically finite (Fig. 2) and a temporary doublet or dipole is thus created. This electronic polarisation due to displacement of the orbits is a property which is shared by all atoms in varying degrees.

Now Clausius and Mosotti in evolving their expressions for the dielectric constant of dielectrics assumed that each molecule could be regarded as a perfectly conducting sphere of radius, a, and that the polarisation of the aggregate of the molecules is the sum of the polarisation of the component molecules.

By this reasoning they deduced that the dielectric constant ϵ could be expressed:—

$$\frac{\epsilon - 1}{\epsilon + 2} \times \frac{M}{d} = \frac{4}{3} \pi N a^3 \quad \ldots\ldots (2)$$

In this equation a is the radius in cms. of the molecule, assumed spherical, M is the mass of 1 mol of the substance, the mass of which in grams is given by the number which is the molecular weight of the substance; thus for example, the molecular weight of hydrogen is 2, so that $M = 2$ grams.

d is the density and N is Avogadro's number which is 6.06×10^{23}. This is the number of molecules in the mass of 1 mol.

For example, for hydrogen gas at 0° C. and 760 m/m. pressure, $d = 0.898 \times 10^{-4}$ gram/cc., so that $M/d = 2.25\ 10^4$ cc. and is the volume of 1 mol.

The assumption based on equation (2) does not give a complete account of polarisation, and the magnitude of the dielectric constant ϵ is now known to be the result of a composite effect due to the three separate actions. For the explanation of this we are indebted to P. Debye for his classical work on the dipole theory which gives us an account of polarisation for liquids of low viscosity.

He recognised that all atoms must have a displacement or optical polarisability. Lorentz showed that if fields of the frequency of light vibrations are impressed upon the substance the molecular refraction R could be given by—

$$R = \frac{(\nu^2 - 1)}{(\nu^2 + 2)} \frac{M}{d} \quad \ldots\ldots (3)$$

where ν is the refractive index of the substance and M and d retain their significance.

However, in accordance with Maxwell's equations, the relationship between the dielectric constant and the refractive index is given by equation (1) so that by substitution of (1) in (3) we have

$$R = \frac{(\epsilon - 1)}{(\epsilon + 2)} \frac{M}{d} \quad \ldots\ldots (4)$$

but it will be observed that the right-hand side of this expression agrees with that on the left-hand side of equation (2), and may be termed electronic polarisation, P_e, hence:

$$R = P_e \frac{(\epsilon - 1)}{(\epsilon + 2)} \frac{M}{d} = \frac{4}{3} \pi N \alpha_e \ldots (5)$$

where α_e is the electric moment of the atom due to the distortion of the electron orbits caused by the electric fields. α_e is a very small number given by the equation

$$\alpha_e = \frac{9}{2} a^3 \quad \ldots\ldots (6)$$

for hydrogen, where a is the radius of the sphere in cms. to which the right-hand side of (2) refers. The diameter of a hydrogen molecule is 2.17×10^{-8} cm., so that it is of the same order of magnitude as the volume.

The quantity $\frac{4}{3} \pi N \alpha_e$ or P_e is obviously independent of tempera-

ture, and therefore does not explain observed phenomena involving heat.

We can now consider Debye's explanation of polarisation, which depends upon the well-known chemical fact that when two atoms combine to form a molecule, (for example: hydrogen (H) and chlorine (Cl) to form hydrochloric acid, HCl) it may be assumed that the electric charges of these respective atoms so neutralise each other's action that they give rise to no external field. On the contrary, other physical considerations point to the conclusion that the H atom retains its positive electric character, and the Cl atom remains negative. We know from the facts of electrolysis that the H atoms and the Cl atoms become dissociated in the solution, the former being a positively charged particle and the latter negatively charged. Such a molecular structure behaves like an electrical dipole, as in Fig. 1.

Before an electric field is applied these dipoles may be orientated in the random manner indicated in Fig. 3.

Such electrical dipoles then act like magnetic dipoles, or small magnets. The difference is that in the case of molecular magnets we have opposite magnetic poles at the ends, whereas in electric dipoles we have opposite charges at an infinitesimal, but mathematically finite, distance l apart as in Fig. 1, and hence the moment

$$\mu = el \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

where e is the unit charge of 4.804×10^{-10} *e.s.u.*

If the polar dielectric which contains the dipoles is not polarised and not under the influence of an electric field all the dipoles neutralise each other and they are orientated in a random manner somewhat similar to magnetic dipoles in a bar of soft iron before it is under the influence of a magnetic field (Fig. 3).

Again, in considering a dipolar molecule we mean a molecule which, as a whole, is considered neutral at a considerable distance in the mathematical sense because the algebraic sum of the positive and negative charges is zero. When the vectors of the individual molecules are orientated in random directions owing to motions caused by normal heat the resulting dipolar moment μ may be regarded as zero.

When an electric field is applied the dipoles will be orientated in a direction parallel to the direction of the field as in Fig. 4 and thus obey the universal law that the tendency of

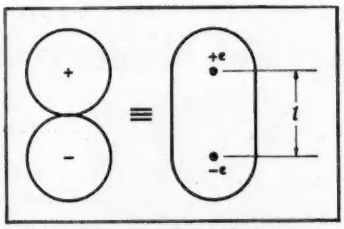


Fig. 2. Formation of a doublet by separation of effective centres of nucleus and orbit charges.

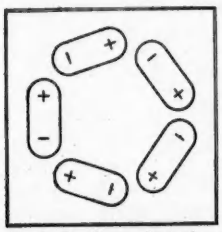


Fig. 3. Random orientation of dipoles before application of electric field.

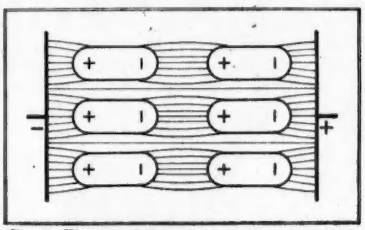


Fig. 4. The application of a field orientating the dipoles along the lines of force.

a system is to reduce the potential energy to a minimum.

The effect of heat is antagonistic to permanent orientation of all the molecules; but the majority will assume parallelism with the applied field and a moment μ of finite magnitude is thus created. If μ is zero the molecule is non-polar and only the term $\frac{4\pi N\alpha_e}{3}$ contributes to the polarisation (except for the atomic polarisation which is expressed by a similar term but which is small enough to neglect for our purpose). This is a particular condition to which the Clausius-Mosotti theory applies.

In order to account for the additional polarisation, P_1, which is contributed by the polarised dipoles, Debye deduced the term $\frac{4\pi N\mu^2}{9kT}$ from similar reasoning to that followed by Langevin when he evolved the theory of pure paramagnetism.

This term is seen to involve the absolute temperature T_0 and Boltzmann's constant $k = 1.372 \times 10^{-16}$ ergs. per degree C.; that is $k = R/N$ where R is the constant of a perfect gas $= 8.315 \times 10^7$ ergs. per degree per gram molecule.

As the temperature rises the increased thermal agitation becomes more and more effective in obstructing the orientation of the dipoles under the influence of the applied field and if T is sufficiently high the contribution of the dipoles, as represented by the term $\frac{4\pi N\mu^2}{9kT}$, to the polarisation becomes negligibly small.

Furthermore, at very high frequencies, such as that ω or $2\pi f > 10^{13}$, the dipoles are unable to follow the cyclic changes of the applied field, and hence their contribution is again negligible. At these frequencies the inertia of the electrons begins to influence their mobility.

This can be explained by representing as the relaxation period of the orientation, and hence the frequency of this as $1/\tau$. Now if the frequency of the applied field is very low compared with this, the polarisation will be in phase with the applied voltage and the value of ϵ_s so obtained may be regarded as the static value. The molecular dipoles will dwell in this polarised position until the applied field again reverses, and since the thermogenic properties of the dipoles depend upon frictional rotation and hence upon the number of rotations in a given time, the heating effect will not be a maximum when the frequency of the applied field is less than the natural frequency of molecular operation.

Conversely, if the frequency of the applied field is greater than that of the polar molecules in their environment at a given instant they will no longer be able to respond fully to the cyclic changes of the field and only partial dipolar orientation will take place, consequently less heat due to friction will be generated.

However, analysis shows that ϵ generally increases with the higher frequencies in the spectrum, beginning at the optical frequencies. This is known as normal dispersion.

If, however, the frequency of the applied field is in resonance with that of the dipoles, then the maximum degree of orientation will take place in the unit time and the optimum heating effect will be produced.

The degree of molecular rotation under the influence of a high frequency field of given voltage gradient will depend also upon the nature of the environment in which the molecule tends to rotate, and also upon the thermal agitation due to temperature rise.

As an example of the order of electric moments μ of polar molecules that for water has been determined by several investigators. The mean value is CHARGE ϵ (e.s.u.s.) $\times$ 1 (cm.) = 1.84 $\times$ 10^{-18} in c.g.s.e. UNITS. Debye derived equations relating μ with T and by observing the variation of ϵ with temperature he was able to evaluate μ.

The total polarisation P_t for such materials at high frequencies is the sum of the electronic, atomic, and dipole polarisations which can be represented by P_e, P_a and P_d respectively and expressed thus :—

$$P_t = P_e + P_a + P_d$$

$$= \frac{\epsilon - 1}{\epsilon + 2}\frac{M}{d} = \frac{4kN}{3}\left\{\alpha_e + \alpha_a + \frac{\mu^2}{3kT}\right\} \quad (8)$$

Since the atomic polarisation $\frac{4\pi N}{3}\alpha_a$ is negligibly small we have

$$\frac{\epsilon - 1}{\epsilon + 2}\frac{M}{d} = \frac{4\pi N}{3} \times \left(\alpha_e + \frac{\mu^2}{3kT}\right) \quad (9)$$

This is exact only for gases and solutions of polar substances in non-polar solvents in which all the individual dipoles may be considered free from the interference of their neighbours.

It is not so in the majority of polar substances, as each dipole is under the influence of the powerful field of its neighbours which may be of the order of megavolts per cm. In consequence the orientation of the dipole is retarded and the value of ϵ is less than that calculated by Eq. (11).

In plastic materials of an amorphous nature, in particular, the molecular rotation will depend upon the frictional effect which may be considered as broadly analogous with viscosity, a property well known to be a function of temperature. Several formulae have been evolved for relating viscosity and temperature; but they differ widely according to the nature of the medium.

For our purpose here we select Vogel's equation which appears to give the greatest accuracy for bitumens, as these have a high temperature coefficient of viscosity. This equation is :—

$$\eta = \exp.\left(\frac{c - h\,(T - b)}{T + b}\right) \quad \ldots\ldots (10)$$

where c, b and h are constants; these will depend upon the type of viscometer and the experimental technique used in the determination of η. T still signifies absolute temperature.

If η is known then the relaxation time at a given temperature may be calculated to a good approximation by the application of Stokes' law; hence :—

$$\tau = 4\pi\,\eta\,a^3/kT$$

where a is the radius of the molecules, which for our purpose are assumed to be spherical.

The equation above indicates that τ is proportional to η/T, and therefore increases very rapidly with fall of temperature.

It has now been proved that Debye's equations are accurate only in cases where the interaction between dipoles can be neglected. These equations assume that the dipoles are free to rotate except for friction.

Later workers, such as Onsager, Garton and Fröhlich have shown, however, that modifications to Debye's theory are necessary to deal with dipolar reactions as they play an important part in the physics of this subject. The full mathematical treatment offers difficulties, but good working approximations are used to deal with these reactions at low and high temperatures.

At zero temperature dipolar activity ceases and therefore makes no contribution to the polarisation, but as the temperature increases up to a certain critical value the dipoles become increasingly active in the process of polarisation.

Conversely, the static dielectric constant ϵ_s reaches its maximum at zero (T_o) temperature.

The new theory may be briefly explained as follows :—

Let E be the strength of the applied field, M the polarisation per unit volume, and ϵ the dielectric constant, which is a function of temperature and frequency of E, then we have :—

$$M = \frac{\epsilon - 1}{4\pi} E \quad \ldots\ldots (11)$$

When static fields are applied to the material we represent the dielectric constant by ϵ_s; but under the influence of A.C. fields this will be complex and can be represented thus :—

$$\epsilon = \epsilon' = j\epsilon'' \quad \ldots\ldots (11A)$$

The real part of the field then becomes :—

$$E = E_o e^{j\omega t} \quad \ldots\ldots (11B)$$

and the energy loss W in the dielectric is given as :—

$$W = \tfrac{1}{2}\,\epsilon''\,E_o^2 \quad \ldots\ldots (11C)$$

When dipolar reactions take place at low temperatures the formula for ϵ_s, the static dielectric constant, is given as :—

$$\epsilon_s = \epsilon_\infty + \frac{16\pi}{3}\cdot\frac{\mu^2 n}{kT}\cdot e^{-W/kT} \quad (11D)$$

for the condition that $(kT << W)$ In this equation n is the number of dipoles per unit volume, and ϵ_∞ is the dielectric constant for pure paraffin. The other symbols retain their significance.

At relatively high temperatures, and when the working frequency is within the radio range, ϵ_s is given by this equation :—

$$\epsilon_s = \epsilon_\infty + \frac{3\epsilon_s}{2\epsilon_s + \epsilon_\infty}\,\frac{\mu^2}{a^3 kT}\left[1 + \frac{1}{3}\,\frac{(\epsilon_s - \epsilon_\infty)^2}{\epsilon_s\epsilon_\infty}\right] \quad \ldots\ldots (11E)$$

This equation is valid until the temperature causes e_s to equal 3ϵ approximately. At very high temperatures $3\epsilon_s/(2\epsilon_s + \epsilon) \approx 1$, and

$$(\epsilon_s - \epsilon)/\epsilon_s\epsilon = 0.$$

Then, if the dipolar molecule is considered spherical for our purpose, $\left(\frac{4\pi}{3}a^3 = \frac{1}{n},\right)$ it can be shown that :

$$\epsilon_s = \epsilon\infty + \frac{4\pi}{3}\,\frac{\mu^2 n}{kT} \quad \ldots\ldots (11F)$$

Using this value of ϵ_s the contribution of the dipoles to the polarisation becomes

$$P = \frac{\mu^2 n}{3kT} \times \frac{2\epsilon_s}{2\epsilon_s + 1} \times E \quad \ldots (11G)$$

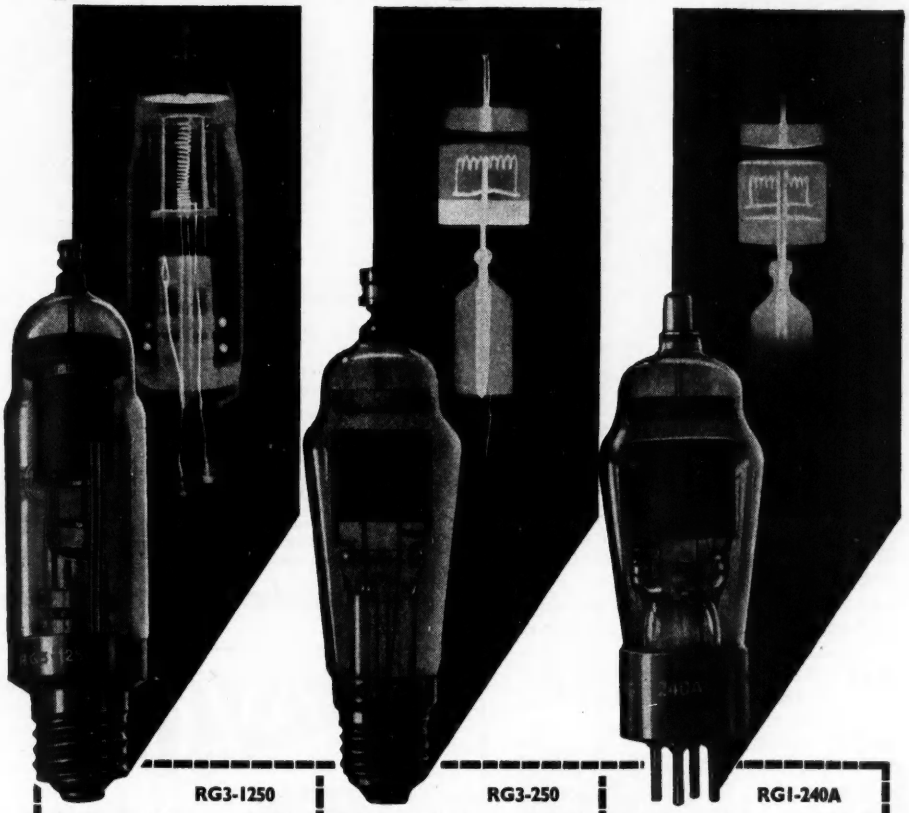
Similarly, in dealing with the dielectric loss, Debye's equations have been modified in order to take into account the interactions between the dipoles in cases where this is important.

These later equations are :

$$\epsilon' = \epsilon_\infty + (\epsilon_s - \epsilon_\infty)F(\omega\tau_o) \quad \ldots\ldots (11H)$$

$$\epsilon'' = (\epsilon_s - \epsilon_\infty)\,\phi\,(\omega\tau_o) \quad \ldots\ldots (11J)$$

Long Life Mercury Vapour Rectifiers



RG3-1250		RG3-250		RG1-240A	
Peak Inverse Voltage	13,000 V.	Peak Inverse Voltage	10,000 V.	Peak Inverse Voltage	4,700 V.
Mean Anode Current	1.25 A.	Mean Anode Current	250 mA. max.	Mean Anode Current	250 mA.
Two Valves in a Single-Phase Full-Wave Circuit will give 3,500 Volts at 2.5 amps.		Two Valves in a Single-Phase Full-Wave Circuit will give 3,150 Volts at 500 mA.		Two Valves in a Single-Phase Full-Wave Circuit will give 1,500 Volts at 500 mA.	
Filament Voltage	4.0 V.	Filament Voltage	2.5 V.	Filament Voltage	4.0 V.
Filament Current	7.0 A. approx.	Filament Current	5.0 A. approx.	Filament Current	2.7 A. approx.

These three Mullard Valves possess all the attributes of good mercury vapour rectifiers *plus* a life expectation above average. That means that their cost per life/hour is remarkably low. All three types are now being widely used in industrial and communications equipment. If you have not tried them yet, write for full technical data.

Mullard

FOR FURTHER DEVELOPMENTS WATCH

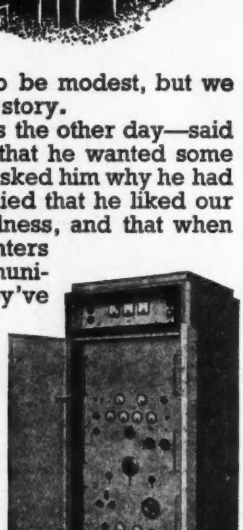
Mullard

THE MASTER VALVE

THE MULLARD WIRELESS SERVICE CO. LTD., TRANSMITTING & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2.

(MVT101A)

We at Rediffusion try to be modest, but we really must tell you this story.
A man came in to see us the other day—said he had an airport and that he wanted some wireless for it. So we asked him why he had come to us and he replied that he liked our up-and-coming youthfulness, and that when up-and-coming youth enters a business like the communications field—well, they've just got to be good.
"Youth!" we exclaimed, "We've been turning out first-class communications gear for over ten years."
"That's young enough for my money," he replied, "When can I have delivery?"



Here's a picture of our Redifon G40, a 500/800 watts M.C.W. and Telephony transmitter which is suitable for ground/aircraft communications services, Navigational Radio Beacons for airways and sea routes, and broadcasting on medium and short waves.

Redifon AIRPORT RADIO

Communications Division
REDIFFUSION LTD., BROOMHILL ROAD, S.W.18
Designers and Manufacturers of Radio Communication and Industrial Electronic Equipment. *Scientific RC102*

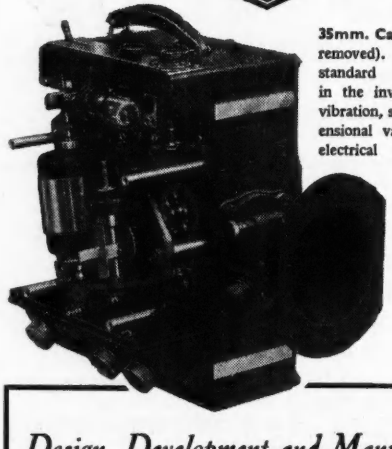
Austinlite
ROTARY SWITCH

A new, heavy-duty 30 amp. switch of robust construction suitable for multi-circuit operations and capable of giving a long and trouble-free life. Can be built up into 1, 2, 3, 4 or 5-cell units providing a large range of contact combinations. Send for folder giving full particulars.

Made by
AUSTINLITE LTD.
(Department J).
LIGHTHOUSE WORKS
SMETHWICK
BIRMINGHAM

A Chance PRODUCT
(Proprietors: CHANCE BROTHERS LTD.)

AVIMO



35mm. Camera (cover removed). Used with standard oscillograph, in the investigation of vibration, stresses, dimensional variations and electrical phenomena.

Design, Development and Manufacture of Optical Mechanical Electrical Instruments

AVIMO LTD. TAUNTON, ENGLAND. Tel. 3634. Grams. 'Avimo'

and $\tan \delta = \frac{\epsilon''}{\epsilon'} = \frac{(\epsilon_s - \epsilon_\infty)\,\phi(\omega\tau_o)}{(\epsilon_\infty + (\epsilon_s - \epsilon_\infty)F(\omega\tau_o)}$ .. (11K)

where $F(\omega T_o) = \int_o^\infty \frac{f\tau}{1 + \omega^2\tau^2} d\tau$ ... (11L)

and $\phi(\omega\tau_o) = \int_o^\infty \frac{f(\tau)\omega\tau}{1 + \omega^2\tau^2} d\tau$ ... (11M)

It has been shown by Fuoss and Kirkwood that $f(\tau)$ can be determined from experimental values of ϵ' and ϵ''.

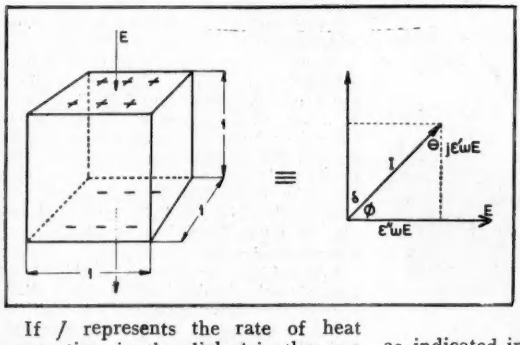
A brief review of later work on the losses in polar dielectrics, to which Dr. H. Fröhlich has made a valuable contribution, may be summarised as follows.

If E represents the field strength, P the polarisation, and D the Maxwell displacement respectively, we have:

$$D = E + 4\pi P \quad \ldots\ldots\ldots\ldots\ldots (12)$$

As already explained, dipolar activity under the influence of applied frequency fields will cause energy loss due to the phase shift of the polarisation.

Then if $E = E_o \cos \omega t$ ..... (13)
we have $P = P_1 \cos \omega t + P_2 \sin \omega t$ ..... (13A)
and $D = E_o \cos \omega t$ ..... (13B)
$+ 4\pi(P_1 \cos \omega t + P_2 \sin \omega t)$
and hence $\frac{dD}{dt}$ = ... (13C)
$-E_o\omega \sin \omega t + 4\pi\omega\,(P_2 \cos \omega t - P_1 \sin \omega t)$



If J represents the rate of heat generation in the dielectric then we have for the rate of change of energy:

$$\frac{dJ}{dt} = \frac{E}{4\pi}\frac{dD}{dt} = \frac{-E_o}{4\pi}(E_o + 4\pi P_1)$$
$\omega \cos \omega t \sin \omega t + E_o P_2 \omega \cos^2 \omega t$) ..... (13D)

Taken over a full cycle the first term disappears. Since $\cos^2\omega t = \frac{1}{2}$ the average loss over a full period is given as:

$$J = E_o P_o \frac{\omega}{2} \quad \ldots\ldots\ldots\ldots\ldots (14)$$

Equation (11A) indicates that for polar materials the dielectric constant is of a complex nature and by differentiation.

$$\frac{de}{dt} = \omega\epsilon'' \quad \ldots\ldots\ldots\ldots\ldots (15)$$

The total current I_t flowing into the dielectric is composed of the charging current and the loss current, and since:

$$E = E_o e_j \omega_e \text{ and } \frac{dE}{dt} = E_o j\omega e^{j\omega t} \ldots (16)$$

$$I_t = \frac{\partial}{\partial t}(\epsilon E) = \epsilon\frac{\partial E}{\partial t} + E\frac{\partial e}{\partial t} \ldots (16A)$$

$$\frac{\partial E}{\partial t}\left(\epsilon - \frac{j}{\omega}\frac{\partial \epsilon}{\partial t}\right) \quad \ldots\ldots\ldots\ldots (16B)$$

after multiplying the numerator and denominator by j. By substituting from Equation (15) the expression for the total current I_t is

$$I_t = \frac{\partial E}{\partial t}(\epsilon' - j\omega\epsilon'') \quad \ldots\ldots\ldots (16C)$$

If it were possible to assume that the dielectric remains constant then for the charging current

$$I_D = \epsilon'\frac{\partial E}{\partial t} = j\omega\epsilon' E \quad \ldots\ldots\ldots (16D)$$

but as already explained ϵ will change with time due to temperature rise, and in consequence the current will lag behind the field, and therefore a phase difference begins to influence the heating effect. The loss current I_L then becomes

$$I_L = -j\epsilon''\frac{dE}{dt} = \epsilon''\omega E \quad \ldots\ldots\ldots (16E)$$

and the tan of the loss angle

$$\delta = \frac{\epsilon''}{\epsilon'} \quad \ldots\ldots\ldots (16F)$$

as indicated in Fig. 5A.

The conductivity of the material in ohms^{-1} cm^{-1} is

$$= \epsilon'\omega \quad \ldots\ldots\ldots\ldots\ldots (17)$$

(To be continued)

A New Range of Glass-based Valves

Mazda and Mullard Miniatures

THE Edison Swan Co., (Mazda Valves) and the Mullard Wireless Service Co. have announced simultaneously the introduction of a new range of all-glass valves using the new B.V.A. B.8.A base.

The heater current in the A.C./D.C. range has been reduced to 0.1 amp. in each type and the bulb size is approximately 20 mm.

The following is a brief specification, and full particulars can be obtained from the manufacturers.

Mazda A.C./D.C. Range

10.C.1. Triode-heptode with performance equal to the TH.233.
10.F.9. H.F. Pentode with g of 2.4 mA/V. Similar to the VP.233.
10.LD.11. Double-diode triode with a mu of 30.
10.P.13. Beam Power Output Pentode, giving 2.5 W with 180 V_a, 165 V_s.
10.P.14. Larger Beam Power Pentode with 28.5 mm. bulb, giving 3.3 W at 165 V_a, 175 V_s.
U.404. ½-wave Rectifier, 250 V r.m.s., 90 mA.

An A.C. Range is also to be introduced with 6.3 V heaters and fitted with the B.8.A base, together with two valves specially designed for television reception. These are the 6.F.13, a high-gain screened H.F. pentode, and the 6.L.18, a triode for local oscillator work, efficient up to 150 Mc/s.

Mullard A.C./D.C. Range

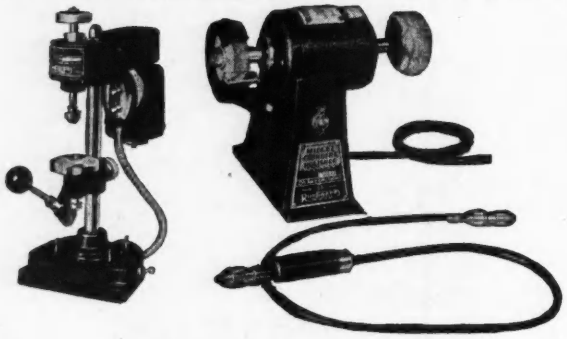
UAF.41. Single - diode - pentode with a g of 1.8 mA/V.
UCH.41. Triode-hexode similar to the CCH.35.
UL.41. Output Pentode with a g of 9.5 mA/V, giving 4.2 W at 165 V_a, V_s.
UY.41. ½-wave Rectifier 250 V r.m.s., 90 mA.

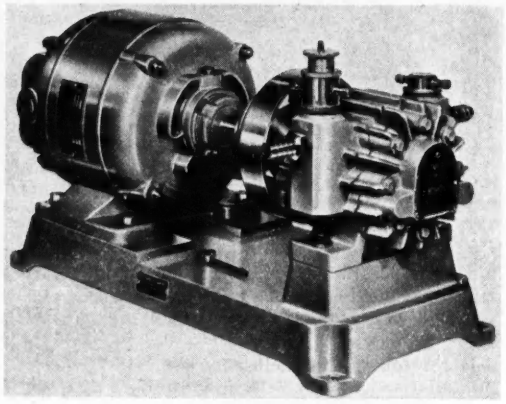
The bases of these valves are not fitted with spigots, and location in the holder is accomplished by the small projecting boss on the side of the base, as described in the specification of the B.V.A. B.8.A base and socket.

For details of the B.8.A base see "Notes from the Industry," p. 235.

SEEN AT THE B.I.F.

Many items of electronic interest shown at the British Industries Fair (May 5–16) are already noted in the report of the Physical Society's Exhibition in the previous month. Some additional noteworthy exhibits are given below, and it is hoped to describe further items later





Left to right: Runbaken midget drill, midget grinder and Edwards' vacuum pump.

Selenium Cells

"Megatron" selenium cells with an exceptionally high open-circuit voltage of 0.2 to 0.3 at 100 F.C. The current output is between 0.5 and 0.65 μA/F.C./sq. cm. active area.

The colour response is sufficiently near the sensitivity of the eye for ordinary purposes, but a correction filter is recommended for use with coloured light.

Megatron Ltd.,
115A, Fonthill Road, N.4.

Self-Amplifying Photo-Cell Unit

By using a barrier-layer cell as a light-modulated rectifier of A.C., sufficient output can be obtained to operate a sturdy relay, the energy being 90 mW. against the normal 0.3 mW.

The associated switch has "on" and "off" contacts in both positions and is spring adjusted for varying degrees of illumination on the cell. Switch rating 270 V 5 A for A.C.; operating time 0.05 sec. The price of the complete equipment, comprising lamp, cell, and switch unit, is 39 guineas f.o.b.

Further details of the operation of the cell under A.C. conditions are given in the paper by J. Sargrove, *Jour. Brit. I.R.E.* 2, 1947.

Sargrove Electronics Ltd.,
Sir Richard's Bridge,
Walton-on-Thames, Surrey.

Alloys for Electronic Industrial Use

A specially high-purity nickel and a nickel manganese alloy have been specially developed for use in radio valve manufacture.

In addition, "Nilo-K," a new alloy simplifies the sealing of metal to medium-hard borosilicate glass.

For thermostatic alloys, both "Nilo" and "Ni-span" are low expansion materials suitable for bimetallic strips and similar applications.

Henry Wiggin and Co., Ltd.,
Wiggin Street, Birmingham 16.

Midget Machine Tools

The high speed midget drill shown above will accomodate drills from 0.01 in. to 0.125 in. and runs at 6,000-10,000 r.p.m. with ball bearing spindle. It is fitted with draw-in chuck collets and weighs 9 lb. Overall dimensions 10 in. by 4 in. by 6 in.

The midget grinder also shown above runs at 15,000 r.p.m. and weighs 4½ lb. A heavier motor can be fitted if required. Numerous attachments are available including a flexible hand tool as shown and scratch brushes, sanding wheels, etc. Size 5¼ in. by 7 in. long.

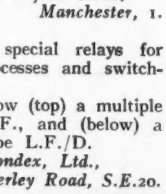
Runbaken Ltd.,
71, Oxford Road,
Manchester, 1.

Relays

A wide range of special relays for remote control of processes and switching operations.

The photographs show (top) a multiple contact relay type L.F., and (below) a double-action relay type L.F./D.

Londex, Ltd.,
207, Anerley Road, S.E.20.



Vacuum Pump and Compressor

A dual purpose pump, particularly useful for school laboratories and small research plant. It can be used for compressed air up to 15 lbs./sq. in. and for evacuating up to 26 in. Hg. The displacement is 3 cu. ft./min., and it will run quietly and continuously without skilled attention. Catalogue ROT.2/1 applies.

Vacuum Gauges

A complete series of mains operated gauges of the Pirani, cold cathode, and ionisation types suitable for a range of 0.0000001 mm. to 10 mm. Hg., with direct reading.

Cathodic sputtering and evaporation equipment is also available to specific inquiries.

W. Edwards and Co. (London) Ltd.,
Kangley Bridge Road, S.E.26.

Flea Contacts

Small spring contacts designed for use with miniature valves having co-planar leads with a spacing of 0.05 in. or more.

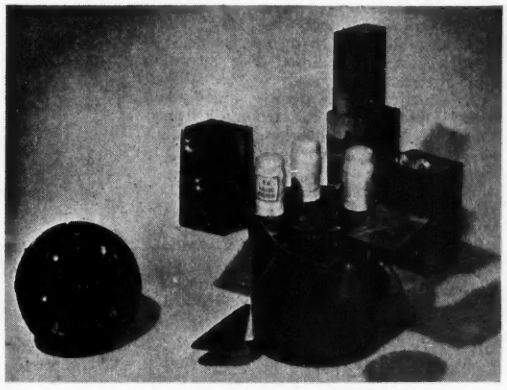
These require holes 0.05 in. sqare in a sheet of insulating material which acts as a support for the valve. The contacts are driven home and grip the leading-out wires securely, while the projection below the baseplate acts as a soldering tag. Made by Instrument Specialities Corpn., Little Falls, N.J., U.S.A., and marketed by *The Park Royal Instrument Co.*

Transformer Components

Interlocking transformer bobbins and pressed-steel lamination clamps (B.P. 553909) manufactured to conform with the standard stampings of Messrs. Magnetic and Electrical Alloys.

A feature of these components is that they can be shipped packed flat for export. All parts are coded and marked. Provision is also made for shrouded types and tag board mounts.

Associated Electronic Engineers, Ltd.,
Stanmore, Middx.



Geiger-Müller Counting Equipment and (top right) typical Beta or Gamma Counter Tube.

(Right): Radio Sonde showing assembly.

Amplifiers and Accessories

An entirely new range of amplifiers consists of one 15 watt, one 50 watt and one 100 watt, and four loud speakers one 6 watt, two 10 watt, one 20/25 watt.

In addition, three experimental loud speaker horns: one 48 in., one 23 in. and one 3-cell horn.

The above range of equipment is for export only, and full details can be obtained on application.

Varite Semi-Conductor. A non-porous ceramic semi-conductor of specific gravity approx. 4.0. A special feature is that it can be manufactured in mass production to close electrical tolerances. Developed for temperature dependent circuits and for use in the measurement of temperatures, it has been found especially suitable for use in the form of resistors in series with A.C./D.C. valve heaters. Its action in this application is to restrict the heater current during the period of warming of the valve heaters, thus preventing a surge of current when switching on and providing protection for the valves and pilot lamp.

Mullard Wireless Service Co.,
Shaftesbury Avenue, W.C.2.

Plastic Materials

In addition to the well-known range of thermoplastics: Bexoid, B.X. PVC, B.X. Polystyrene, etc., two other items of interest are "Styrafoil," an orientated toughened foil, and "Styrathread," extended tensilised (*sic*) threads of polystyrene, suitabe for H.F. cables.

B.X. Plastics, Ltd.,
Higham Station Avenue,
London, E.4.

Components and Kits

Complete kits for amplifier and receiver construction, with other components suitable for amateur and experimental use.

Lee Products, Ltd.,
Radio House,
East Street, Brighton.

Radio Sonde

A miniature radio transmitter is attached to a balloon 6 ft. in diameter and soars into the stratosphere, descending again by parachute. As it rises it transmits signals which depend on the prevailing meteorological conditions i.e. temperature, humidity, and barometric pressure. These signals provide accurate data for use in the preparation of weather reports. The Radio Sonde has been officially adopted by the Air Ministry.

Measurements of the upper winds are also obtained by plotting the flight of the balloon.

Slow Motion Precision Drive

This drive has been designed to meet the need for a dial covering 360° rotation. The reduction is carried out by means of a double friction epicyclic mechanism located in a dustproof bakelite housing. Ratio approx. 44-1, torque 12 in./ozs. before slipping.

Salford Electrical Instrument Co., Ltd.,
Peel Works, Salford, Lancs.

Geiger-Müller Equipment

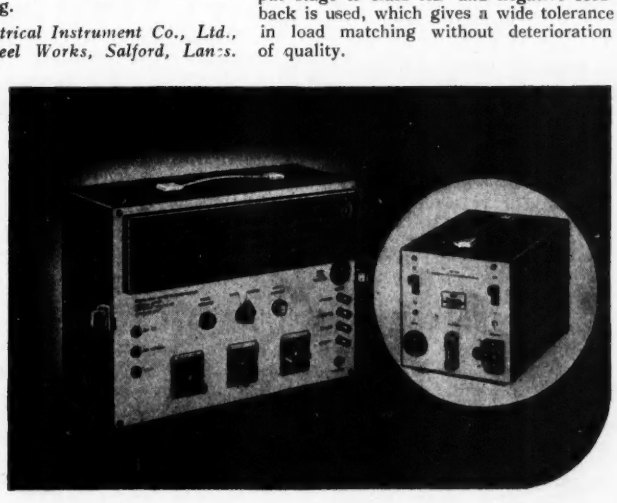
This equipment is capable of counting up to 600 p.m. electro-mechanically and incorporates an electronic meter for higher rates. When used with the standard G-M tube quantities of the order of 0.1 microgramme of radium can be measured at 1 m. Price £150 complete.

A Graves-Tomes Gamma Counter tube is also shown, suitable for cosmic ray or radioactivity measurements. Threshold volts 1,000, plateau 250-300 V Av. background count 180. Price £8.

Alltools, Ltd.,
2, Transport Avenue,
Great West Road, Brentford.

Amplifiers

A portable amplifier type PA.20 with 20 W undistorted output, with an input suitable for dynamic or crystal microphone or gramophone pickup. The output stage is class AB and negative feedback is used, which gives a wide tolerance in load matching without deterioration of quality.



Type PA.20 Amplifier

—B.S.R.

Specification: Frequency response 30-14,000 c/s. Distortion less than 4 per cent. at full output. Power consumption: 115 W at 230 V or 10 A at 12 V with converter. Weight 34½ lb. Dimensions 18 in. by 13 in. by 8½ in.

The recording amplifier type R.1, which is illustrated with the PA.20, has been designed for direct disk recording and also has an output of 20 W. A correction network giving independent change-over switch for recording, playback, or PA reproduction. Continuous recording can be made by connecting a second recorder in the PA position.

Specification: Frequency response 30-15,000 c/s (without controls) ± 2 db. Distortion less than 5 per cent. at 20 W. Hum 60 db. below max. output. Volume level indicator. Weight 35 lb. Dimensions as above.

Birmingham Sound Reproducers, Ltd., Old Hill, Staffordshire.

Disk Recording Equipment

The Audix Recorder Type Rx5 is a portable equipment designed to give "studio equipment" results with simplicity in operation. The traversing gear is driven from the turntable centre and can give either 96 or 110 grooves/in. with disks up to 12 in. diameter. The cutting head is raised and lowered by an eccentric cross-bearer, and the lead screw can be accelerated by hand for run-off scrolls.

The overall dimensions are 20 in. by 17 in. by 13 in.—wooden case.

Cutter.—Operates on the torsion rod principle, requiring an input of 3 W. Nominal input impedance 200Ω at 1,000 c/s. Response with the amplifier supplied is level from 50 to 8,000 c/s. Playback is by means of a "Connoisseur" pickup and change-over switch, which also enables monitoring to be done with a 15Ω speaker.

Prices.—Recorder complete with amplifier and peak level meter, incorporating playback, £160.

As above but with pitch selector mechanism omitted, £154.

Smaller equipment, Type Rx7, £106.

Recorder mechanism only (Rx5), £105.

Further details on request from *Audix Ltd., Sheldrake House, S.E.5.*

A Microsecond Flash Tube

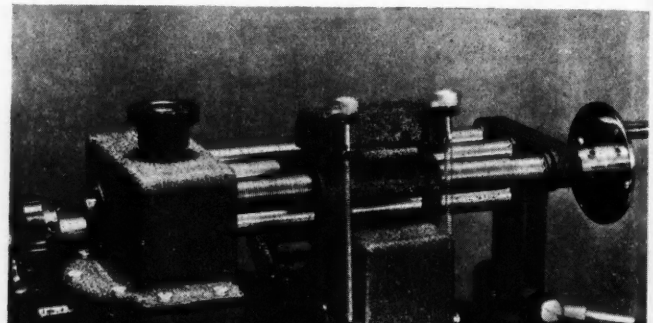
The Mullard LSD.2 Flash Tube is a further development of the "Arditron" tube used during the war for the photographic examination of projectiles in flight, and is a high intensity light source operated by condenser discharge.

To obtain a flash of approximately 1 μsec. duration, an operating potential of 7500 V. and a capacitance of 3μF. is used. This corresponds to an energy content of 100 joules and an instantaneous power dissipation of some 100 MW. The trigger pulse is an oscillatory transient of 3,000 V.

The tube is intended for single flash operation only and is not intended for use as a stroboscopic lamp. The envelope contains a copper rod cold cathode, a copper anode and a ring electrode which acts as a trigger. In order to ensure reliable triggering, the electrodes are potassium activated. A useful life of some thousands of flashes may be expected, the intensity gradually diminishing due to metal being sputtered on to the bulb walls.

The peak energy it at a wavelength of approximately 4200 A. and good results are obtainable with panchromatic emulsions. The total light emission provides effective illumination over a wide area at a distance of 12 ft., and higher loadings will give adequate illumination up to 30 ft.

Further particulars can be obtained from the *Mullard Wireless Service Co., Century House, Shaftesbury Avenue, W.C.2.*



Close-up of cutting head and traversing carriage of Audix recorder. The depth of cut is adjusted by the two suspension screws on either side of the cutter.

ELECTRONICS EXHIBITION

The Second Annual Electronics Exhibition will be held by the Institution of Electronics at the Great Hall, College of Technology, Manchester, on the following dates:— July 22nd Tuesday — 2.30 p.m.–9 p.m. July 23rd Wednesday — 10 a.m.–9 p.m.

Admission will be by ticket only. Non-members may obtain tickets on application to Mr. A. Coates, 16, Didsbury Park, Manchester, 20. *Telephone* DID. 4545.

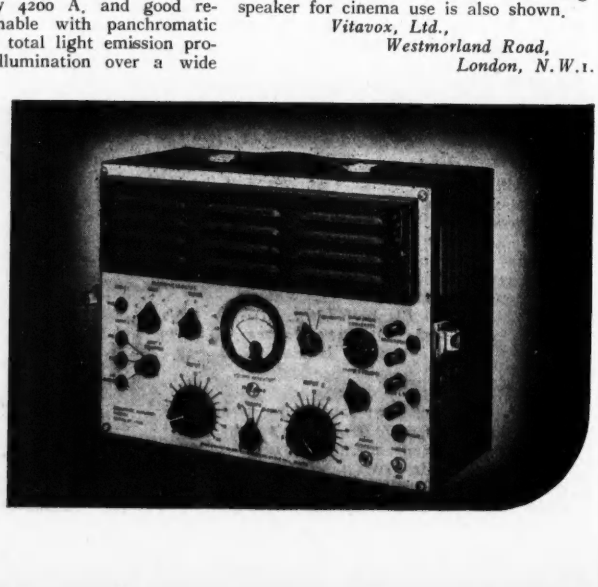
Electronic Engineering will be represented and will be pleased to meet Manchester readers and others.

Special P.A. Loudspeaker

The "Bitone" reproducer, designed for use in small halls and cinemas, consists of a multi-cellular horn and moving coil pressure unit with a 11 in. moving coil speaker in a vented enclosure for bass reproduction. A cross-over filter network divides the frequency spectrum between the two units.

A full size double channel wide range speaker for cinema use is also shown.

Vitavox, Ltd., Westmorland Road, London, N.W.1.



Type R.1. Recording Amplifier

—B.S.R.

NOTES FROM THE INDUSTRY

B8A Valve Base

The essential details of the B8A base have already been announced. This is an 8-pin base of pressed glass construction which uses a raised boss on the side of the base shell as a means of location and retention. The base also carries a centre spigot not fitted with either a key or groove and therefore not constituting the means of location or retention.

It has now been agreed to admit as standard a spigotless version of the same base. The ultimate aim of the industry is to establish a standard range of valves which will be mechanically and electrically interchangeable in the appropriate holders; it is therefore essential that all valve holders used for the B8A base shall be designed to accommodate both versions.

The B8A base is at present being used only by some valve manufacturers for some individual valve types, but the B.V.A. is at work on the development of a standard range of valves and this new range will employ the B8A base for those types where it is appropriate. The two versions of the base will both be in use by the valve manufacturers, but the necessary interchangeability between valves of the same type in the ultimate standard range, from different sources of supply, will be fully maintained.

Telcon Cables for Radio Frequencies

The new Telcon R.F. Cable publication (No. 10—1947) contains a great deal of useful information including a chapter dealing with the fundamentals of R.F. cables under the heading "Radio Frequency Cable Constants," and data for equipment designers in which bending radii and tolerances for drilling are tabulated. The physical and electrical properties of Telcothene and Telcovin (PVC) are quoted and the maximum power ratings and working voltages are given for certain types of cables. Another useful feature is the inclusion of cable attenuation curves and a chart showing some recommended types of cables for various purposes. Applications for copies of this catalogue can be sent to The Telegraph Construction and Maintenance Co., Ltd., Telcon Works, Greenwich, S.E.10.

Phillips' New Communications Receiver

Details of a new general purpose receiver for communications work are released by Phillips Transmission (Phillips Lamps, Ltd.). The receiver, type F.O. 509, is suitable for the reception of A.M., F.M. or C.W. types of transmission and is sturdily built to stand considerable rough usage without damage. Its sealed construction renders it waterproof and almost completely airtight, and for further protection a silica gel dessicator is inserted through the front panel to absorb any moisture that may enter the set. The receiver will continue to operate even if totally immersed in water.

The wave range is in four bands: 12.0-20.0 Mc/s., 5.2-12.0 Mc/s., 2.2-5.2 Mc/s., and 1.0-2.2 Mc/s. A 6-volt 1.65 amp. D.C. supply is required for feeding the filaments and an internal vibrator; the latter produces 100 volts at 26 mA. for the H.T. supply. The width of the receiver is 12.5 in., depth 9 in. and height 8.5 in. The weight is approximately 21 lb.

Neodex

Neodex glass has been designed by Chance Bros., Ltd., of Smethwick, for the use of operators engaged in lamp-working glass. When glass is heated in a flame, sodium vapour is volatilised from the glass and the flame is coloured yellow which makes it difficult to see the glass. In addition, the infra-red radiation from the white hot glass is liable to damage eyes which are exposed to it for a long period, and the intense brightness of the hot glass may cause discomfort due to glare.

The colour of Neodex is a slightly greenish-blue neutral and practical tests have shown that this colour does not interfere in any way with the judgment of the lamp worker, while the high absorption in the yellow region enables the shape of the glass being worked to be followed without interference from sodium glare.

Supplies are at present limited and distribution is being handled by Safety Products, Ltd., (who also mount Neodex in spectacle frames and goggles), to whom all inquiries should be addressed at 44 Hatton Garden, London, E.C.1.

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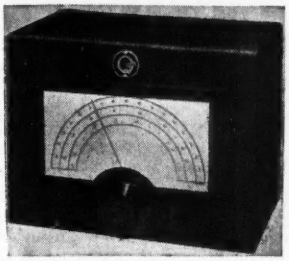

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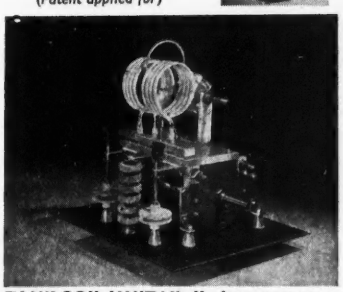

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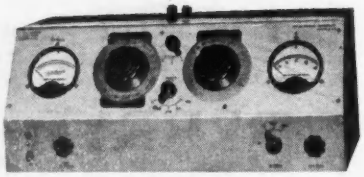

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X-Rays in Practice

Wayne T. Sproull, (McGraw-Hill Book Company, Incorporated, London and New York, 1946. $6.00. 615 pp.)

This book is a welcome addition to the literature on X-rays, particularly as a reference volume. It should also prove useful as a text book for advanced students of physics and radiology, whose needs are further catered for by a list of questions at the end of each chapter. Although the book contains little that is new its value lies in the fact that it provides a detailed review of the fundamental theory and practice of X-rays, much of which has previously been scattered throughout scientific literature. There are few aspects of X-rays which are not mentioned, as is indicated by the extensive index which fills two columns of each of twenty-two pages. It is true that some of the subjects touched upon can hardly be regarded as a part of X-ray science, as for instance, notes on the atomic bomb, and how to build a high voltage condenser, but these are characteristic of the wide scope of the text.

The author's approach to the subject is that of the industrial physicist, and this probably explains the unbalanced nature of the contents. Of the 615 pages, 237 are devoted to X-ray crystal analysis, 28 to the medical applications of X-rays and 60 to industrial radiography and miscellaneous applications. The rest are devoted to chapters on fundamental theory, X-ray generating equipment, radio-activity, protection, X-ray detection and measurement, and to tables of wavelengths, absorption coefficients and crystallographic data.

The fundamental physics of X-rays and gamma-rays is reviewed in considerable detail, and many will welcome the derivations of some of the formulæ. As a consequence, however, the reader must have a sound knowledge of fairly advanced mathematics, although a genuine attempt is made to interpret such sections for those unskilled in this subject.

Throughout the text there are many statements which would be challenged by the specialist, indicating that the author is not always writing from first-hand experience, but instead on material culled from the many publications for which the references are given. On page 405, the author mentions the preparation of metal powder specimens, without any reference to the precautions that must be observed in filing or of the need for annealing. It is not until page 521 that the necessity for annealing is mentioned, and even then only casually in the course of a note on Phragmen's work on copper-zinc alloys. Experienced radiographers will question the validity of the recommendation (page 184) that tray development should be used for radiographs on the grounds of economy of developer and fixer, if the radiographic darkroom handles fewer than 100 films per day. It is surprising to find on page 140 that it is *exceptional* to connect the milliammeter in the grounded part of the high voltage circuit. The definition of the absorption coefficient (page 72) as the fraction of energy absorbed per *cubic centimetre* is particularly unfortunate.

Despite many minor shortcomings of this kind, all who are interested in X-ray technology will value the book as an up-to-date and well indexed survey of a rapidly expanding science.

L. MULLINS

Fundamentals of Industrial Electronic Circuits

Walther Richter (McGraw-Hill Co., $4.50).

In the Preface the author makes a statement with which the reviewer is fully in agreement: "The text is in no way meant to replace such excellent books as Herbert J. Reich's *Theory and Application of Electron Tubes,* and the book *Applied Electronics,* by the M.I.T. Staff. . . ."

It is difficult to see how and in what way competition might arise. The book under review has been written for students attending evening classes, a relatively large proportion of them being unfamiliar with mathematical methods using the calculus, etc. But this in itself is hardly an excuse for the use of such phrases as "A vector is nothing but a stick fastened to the shaft of a motor and throwing a shadow on a screen. . . " (p. 42), or: ". . . can be found by adding the shadow lengths thrown by the vectors . . ." (p. 46).

In fact, the shadows thrown by the vectors overshadow the whole book.

The reviewer, who, like the author, is proud of many years' teaching experience at evening classes, considers it of no assistance to the mathematically uneducated if mathematical definitions are conveyed to him in a cloak of childish phrases. After all, the explanation of the vector as a quantity which has both magnitude and direction is intelligible to most students, and if they are considered unfit to be given a mathematical explanation of a phenomenon—then don't try.

The writing is not always as accurate as desirable. For example, the author explains the r.m.s. value by saying (p. 40) "we had to square the individual current values," where instantaneous is properly meant. On p. 159 he states that "the battery is found by drawing a line with a slope given by the plate resistance," where the voltage of the battery is obviously meant. Such phrases are scarcely admissible in a book which addresses itself to students in evening classes.

REVIEWS

Although the title is " Fundamentals of Industrial Electronic Circuits," very little mention is made of industrial circuits in the 27 chapters of the book, and it would be preferable to call it " Fundamentals of Electronic Circuits." Unfortunately it shows no new ways or means of approach to the fascinating problem of how to teach the " interested but not previously trained or qualified " members of the industry.

W. SUMMER

Calculating Machines

Prof. D. R. Hartree, F.R.S. (Cambriged University Press). 40 pp. 2s. net.

This monograph contains the subject matter of the author's inaugural lecture as Plummer Professor of Mathematical Physics at Cambridge. Professor Hartree is peculiarly qualified to speak on the development and future possibilities of calculating machines from first hand experience and has covered the subject in a concise and lucid exposition.

How far the ENIAC departs from the non-technical conception of an " electronic brain " is shown by the author's remark: " . . . if the divisor happens to be zero, a human computer might do various things but would certainly *not* go on for ever trying to divide by zero, which is what the machine *would* do unless it had been specifically instructed not to."

Finally: " Development of these machines will certainly have a considerable impact on mathematical physics, though its effect will depend on the readiness of mathematical physicists to seize and exploit the opportunities offered by the new facilities they provide."

G.P.

The Intelligent Use of the Microscope

C. W. Oliver, A.M.I.E.E., F.R.M.S. (Chapman & Hall, Ltd.) 176 pp. 53 figures. 12/6.

This book is a guide to the proper understanding and use of the microscope rather than an advanced text book; and, as such, should be a valuable addition to the range of existing books on the microscope and microscopy.

There is no doubt that many workers who use the microscope every day for routine examinations do not know how the instrument should be set **up and used**; and, in consequence, fail to get from their equipment anything like its proper performance. There are hundreds of workers in this class who *are quite* satisfied if any sort of image can be seen on looking into the instrument. In such cases it is safe to say that the image will probably be of poor optical quality.

It is not appreciated that the microscope is a more complicated optical instrument than say the telescope, in which the user cannot control the illumination of the object under observation.

In microscopy, the proper illumination of the object is of the utmost importance and unless the principles underlying this technique are understood and applied, the performance of a first class objective may be entirely ruined.

Considerable attention is given in the book to the correct methods of illumination and the general principles are clearly set out. No user of the microscope will now be able to plead ignorance of the essential rules to be observed in the use of his instrument.

For the above reasons alone, the book should be of great value to many microscopists who wish to improve their technique and get the best out of their equipment without an undue amount of reading in advanced text books.

Chapters are devoted to optical theory, numerical aperture and resolution, the microscope, its components and accessories, selecting equipment, illumination, the microscope in use, measurements and counts, colour filters, photomicrography, and special instruments and applications.

The chapters dealing with colour filters and with photomicrography are simple in outline and suited only for the beginner. Those wishing to progress further can however select standard text books from the full bibliography given at the end of the volume.

The book is well written, very readable and remarkably free from errors. It can be thoroughly recommended to all users of the microscope who are not already expert in the technique of setting up and manipulating their instruments.

R. M. WESTON

Radio Receiver Servicing and Maintenance

E. J. G. Lewis (4th Edition). (Sir I. Pitman & Sons 8s. 6d. net).

This book, which was first published in 1933, has had a deservedly steady sale and the new edition has appeared at the right time for the numbers of ex-service engineers who are taking up radio repair and servicing work.

Sufficient theory has been included to avoid making the tests a matter of blind following of instructions laid down, and the reader should be able to acquire a considerable amount of working knowledge of radio from a careful study of the book.

A chapter on A.C.-D.C. and midget receivers has been included in the present edition to cover the influx of these sets during recent years, and there are numerous circuit diagrams illustrating these and other standard types. The book can be recommended both to the newcomer and the experienced radio dealer.

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CORRESPONDENCE

The Synchrodyne

From the number of letters and comments received, the article by Dr. D. G. Tucker in the March issue aroused a great deal of interest. In thanking correspondents for their letters we are pleased to say that arrangements have been made for the publication of further articles on the design and construction of a Synchrodyne receiver.—Ed.

Dear Sir,

The article on the "Synchrodyne" by D. G. Tucker in the March issue of ELECTRONIC ENGINEERING is extremely interesting, but there are a few points on which I would like to comment.

The heading reads "A New Type of Radio Receiver for A.M. Signals," but the principle was suggested many years ago under the name "Homodyne" and has in fact been used in the laboratory. For example any "straight" set using reaction can be adjusted to lock on a strong signal if the tuning and reaction controls are carefully adjusted and I have used a standard communication type receiver with the B.F.O. adjusted to zero beat (when locking occurred) to provide this form of reception; some super-regenerative receivers can be operated in substantially the same mode.

The "powerful beat note" which occurs when the oscillator is not tuned within the synchronising range can hardly be acceptable in a domestic receiver and its suppression would be essential if the method is to compete with existing receivers.

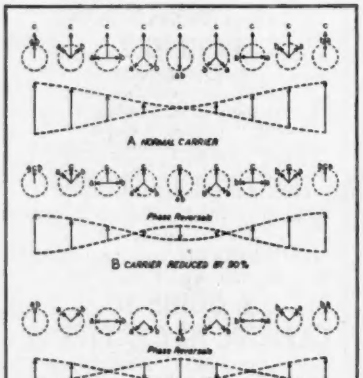

Fig. 1

A method tried in the U.S.A. which does not suffer from the "howl" is described as "exalted carrier reception" and does not utilise a free oscillator; instead the carrier is filtered and amplified before being recombined with the received signal in the correct phase. The purpose in this case is to reduce selective fading distortion rather than to provide detector discrimination, although the latter effect is of course obtained. In fact the main advantage of true "Homodyne" reception is that it can provide almost complete elimination of selective fading distortion and the reception of suppressed carrier transmission, which is not possible with either the "synchrodyne" or "exalted carrier reception" methods as explained below.

The main cause of distortion when selective fading occurs is due to the reduction of the carrier, relative to the sidebands, to such an extent that the vector sum changes phase by 180°, resulting in a discontinuous carrier phase and severe envelope distortion. This is illustrated for a 100 per cent. modulated wave in Fig. 1 for the conditions of normal carrier, carrier reduced by 50 per cent. and carrier absent.

If the locally produced oscillation is synchronised with the received signal the local oscillation will change phase in the same way as the signal and the distorted envelope will be reproduced in substantially the same way as with a receiver employing no demodulating oscillator; hence both "synchrodyne" and "exalted carrier" systems will fail to correct this distortion.

To overcome this difficulty the local oscillation must not contain the 180° phase changes indicated in Fig. 1 and hence it is first necessary to derive a wave from the received signal which does not contain such phase changes, so that it can be used to provide a steady phase synchronising signal. This is readily provided by full-wave rectifying or producing a harmonic of the received signal, which can then be filtered, limited and applied to the local oscillator, since it is possible to use a harmonic to lock the local oscillator to the fundamental. Since each pair of sidebands in the received signal will, when rectified, produce the second harmonic of the carrier a substantial second harmonic component should be present even if the carrier is absent, as in suppressed carrier transmission or when selective fading eliminates the carrier from a normal transmission.

The name "Synchrodyne" is excellent for a circuit in which the local oscillation is synchronised with the signal *as received;* "Homodyne" can be used for the arrangement suggested above using a harmonic for synchronisation, since it appears to satisfy the requirements originally stated for this method many years ago. Both systems would, of course, have the advantages of small effective modulation depth and detector discrimination. (See Fig. 2.)

One method of avoiding the "howl" when tuning in would be to use an oscillator with sufficient fixed negative bias to prevent oscillation in the absence of an adequate synchronising signal. Alternatively the D.C. output from the demodulator might be used to control a muting voltage so that only a quiet "howl," suitable as a tuning indicator, was produced, although the normal "magic eye" would be preferable since if the receiver were tuned to the edge of the synchronising range a reduction in signal might result in the local oscillator running free and "howling"

In conclusion, may I say how grateful I am for the information given in the article and express the hope that a further one will appear in due course. It would be interesting to compare the performance of such systems with F.M., particularly with regard to interference from electrical appliances, static and other obstacles to high quality reception.

Yours faithfully,

FELIX G. APTHORPE.

N. Berwick.

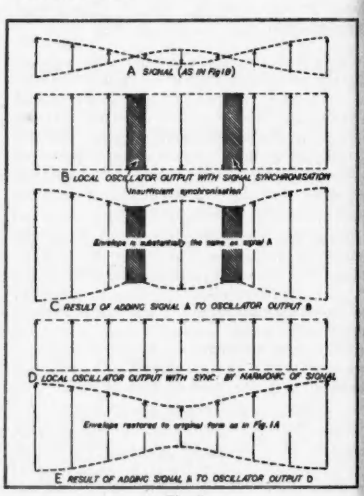
A SIGNAL (AS IN Fig 1B)
B LOCAL OSCILLATOR OUTPUT WITH SIGNAL SYNCHRONISATION
Insufficient synchronisation
Envelope is substantially the same as signal A
C RESULT OF ADDING SIGNAL A TO OSCILLATOR OUTPUT B
D LOCAL OSCILLATOR OUTPUT WITH SYNC. BY HARMONIC OF SIGNAL
Envelope restored to original form as in Fig. 1A
E RESULT OF ADDING SIGNAL A TO OSCILLATOR OUTPUT D

Fig. 2

Dr. Tucker Replies :

Mr. Apthorpe's letter is a very useful contribution, and his discussion of the advantages of harmonic synchronisation is particularly interesting. His system appears to offer a solution to the problem of carrier suppression (intentional or through fading), but it is evidently a much more complicated system than the synchrodyne, involving a good deal of auxiliary equipment (rectifier network, amplifier, etc.), and would be more difficult to operate, since synchronisation to harmonic frequencies is far more unreliable than it is to the fundamental.

I am glad to have this opportunity to refer to the Homodyne receiver; Mr. Apthorpe uses the name, but I think he is wrong in his use of it. At first, he says it is the same as my Synchrodyne, but later he uses it for his harmonic synchronisation system; this is, of course, contradictory. In actual fact, both these uses are wrong. The Homodyne was described by Colebrook[1] in 1924, and the circuit is given in the figure overleaf. It will be seen that the incoming signal is subjected to the full frequency discrimination of a regenerative tuned circuit, and

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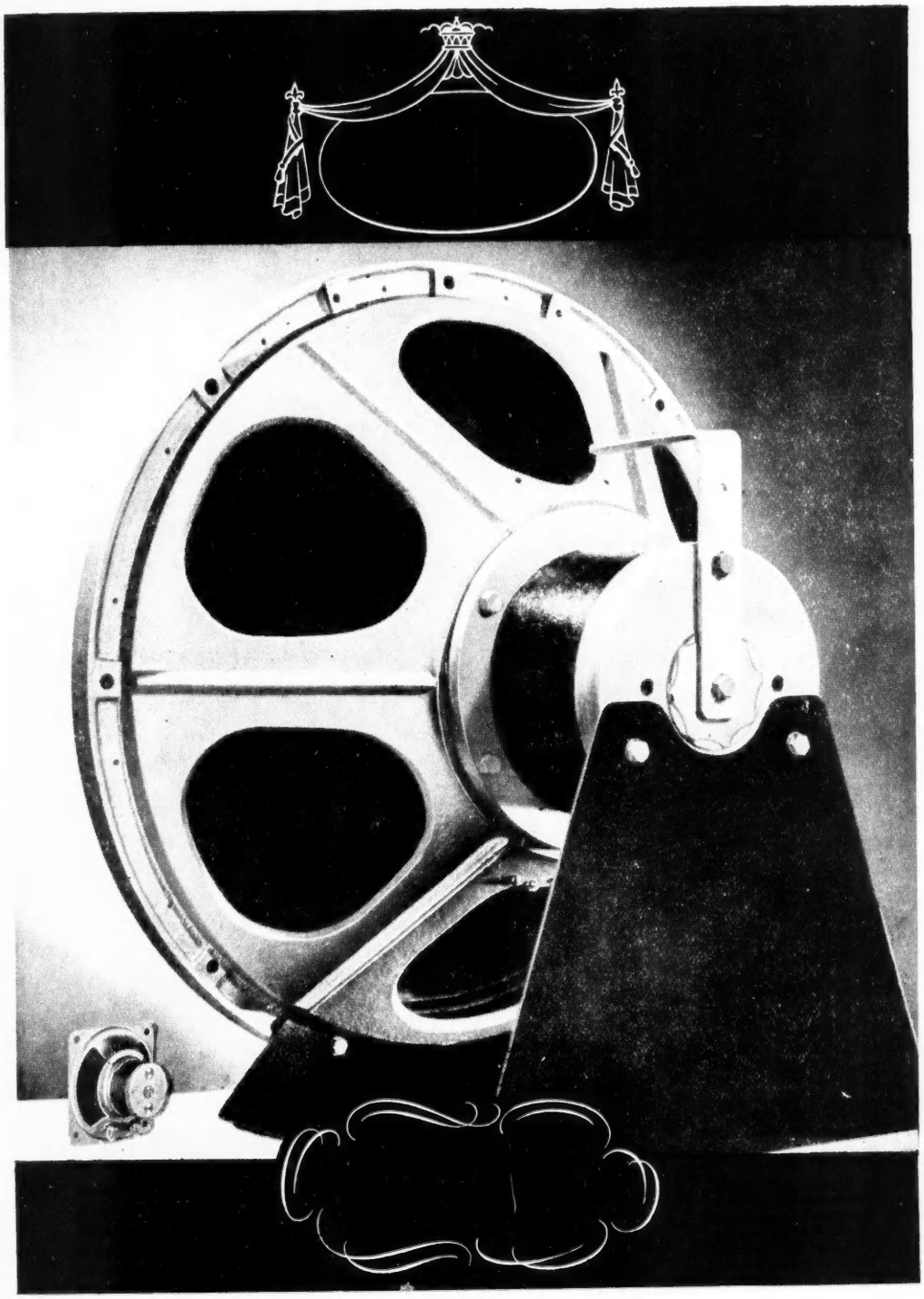

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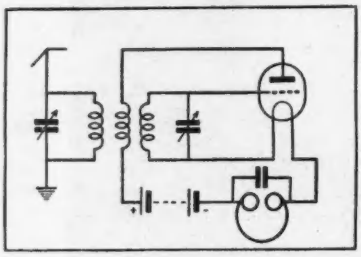


the frequency response of the audio output must be very poor. In fact, the Homodyne suffers from the same difficulty as almost all receivers, i.e. selectivity and quality are mutually incompatible—and it gives selectivity in preference to quality. The important point about the synchrodyne is that selectivity and quality are quite independent, and both may be excellent. The " exalted carrier " system of reception is really more akin to the synchrodyne than is the homodyne, but it loses the valuable discriminative properties of the synchronised oscillator, and is rather more expensive.

Yours faithfully,

D. G. TUCKER.

Reference.

(1) F. M. Colebrook, "Homodyne," *Wireless World and Radio Review*, 13, pp. 645-8 (1924).

Recent Advances in Steel Wire Magnetic Recording

Some readers may recall a series of articles published in ELECTRONICS, TELEVISION AND SHORT WAVE WORLD in the early months of 1940, describing a steel wire magnetic recorder designed by myself.

This machine aroused considerable interest judging by the correspondence I received but there was also criticism, some justified, but, as recent events have shown, mostly unjustified, due to an erroneous conception of the principles of wire recording.

One of the main objections raised was that wire could never be equal to tape for high fidelity recording because of the distortion produced by the wire rotating axially as it passes through the head. As this seemed to be true at the time, wire recording gave way to tape for quality recording.

I have retained a keen interest in wire recording and its problems since designing the machine and following a recent demonstration my faith in this method of recording appears to have been justified.

The demonstration was given at a meeting of the British Sound Recording Association on a wire recorder designed by Mr. P. T. Hobson and the staff of Messrs. Boosey and Hawkes.

This machine incorporated the latest researches on wire recording and all those present, including many experts were agreed that the quality of recording (in this case a full orchestra) was of the highest quality and in every way equal and even superior to steel tape.

This great advance is due to a comprehensive study of the magnetic problems involved, the development of new alloys for the wire improvements in the mechanics of the machine and the use of high frequency bias.

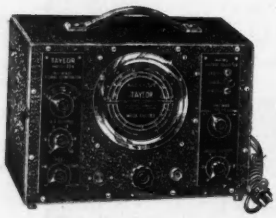
Following this demonstration there is no doubt that wire recording has virtually been " reborn " after a comparatively obscure existence of some fifty years for high fidelity recording and Mr. Hobson and his colleagues are to be congratulated on the development of a machine which has once again brought it to the fore.

With its ease of handling and storing the wire and the simpler mechanical problems involved we shall be hearing much more of wire recording in the near future and meanwhile the theories of wire recording in vogue during the past few years will have to be revised in view of Mr. Hobson's work.

RONALD L. MANSI.

Orpington, Kent.

A full report of this lecture is appearing shortly.—Ed.



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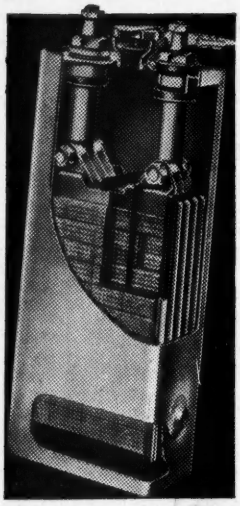

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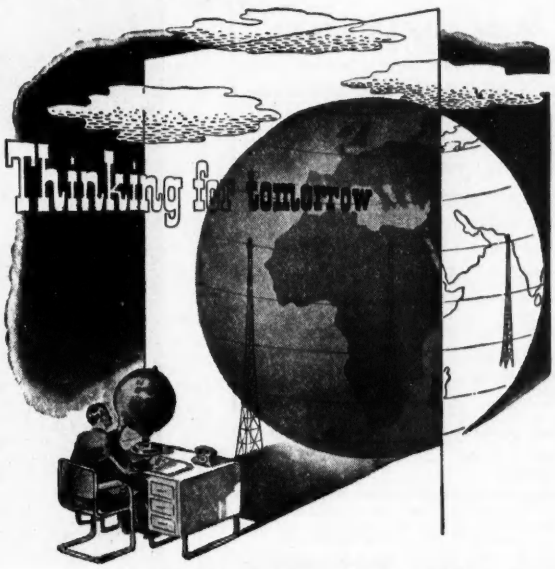

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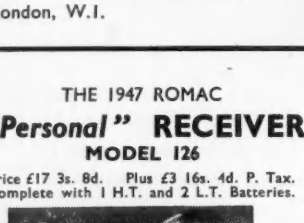

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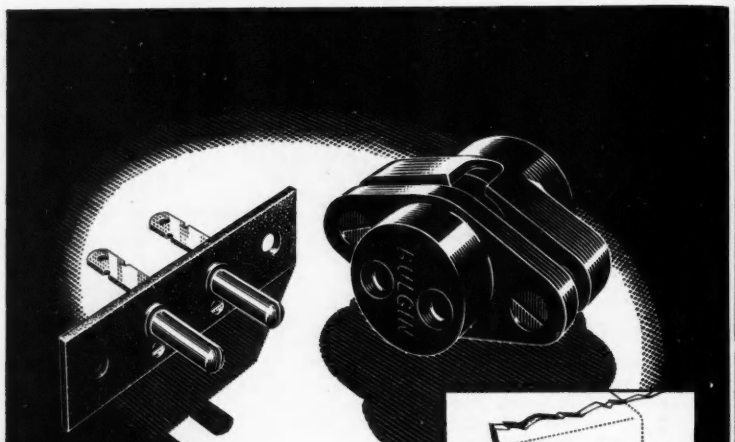

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THE PROPRIETORS of British Patent No. 564,382, relating to electronic translating devices, are desirous of entering into arrangements by way of licence or otherwise, on reasonable terms, for the purposes of exploiting the same and ensuring its full development and practical working in this country. Interested parties who desire a copy of the patent specification and further particulars should apply to Arthur W. Parfitt, of Stafford House, Norfolk Street, London, W.C.2.

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PHYSICIST for production and laboratory assistant required immediately by manufacturers of mercury vapour discharge appliances. Experience in electronics an advantage. Detailed application, stating salary etc., to Box 051, "Elec. Engg."

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RADIO COMPONENT and electronic engineering organisation require sales manager. The company, marketing products solely to manufacturers, need a man thoroughly conversant with the radio market, with personality and initiative and the ability to negotiate at director level. He must be able to justify a four-figure salary and possess adequate technical knowledge. Write, stating experience, age and salary required, to Box 047, "Elec. Engg."

PHYSICIST or electrical engineer for research and development work in electro acoustics and recording. Suitable applicant must have sound theoretical training and practical experience in the work. Reply, stating age, experience, and salary required, to Box 045, "Elec. Engg."

PHYSICIST required to undertake development work on photo-electrical cells, G.M. tubes, and similar electronic devices. Applicants should have experience in high vacuum laboratory techniques and also the ability to take over the manufacture of small quantities of these special devices. Salary according to age, qualifications and experience. Apply in writing to Box 044, "Elec. Engg."

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LEADING COMPONENT manufacturers require the services of a graduate radio engineer to carry out research and development programmes in connection with electronic components, fuses and suppressors. Good background in general physics and some inventive ability essential. Salary will be in accordance with qualifications and experience, but will not exceed £500 per annum. Give full details of age, education and experience. Box 043, "Elec. Engg."

CLASSIFIED ANNOUNCEMENTS (CONT.)

PHYSICISTS and electrical engineers required for work on radar and radio navigational equipment. Experience in radio research or development is essential, an honours degree desirable. Several vacancies exist within the salary range £400-£900, dependent on qualifications and experience. Application forms are obtainable from the Personnel Manager, Ferranti Ltd., Ferry Road, Edinburgh, 5.

ASSOCIATED Electrical Industries, Ltd., Research Laboratory, Aldermaston Court, Nr. Reading; capable laboratory technician or graduate required to work on electron microscope specimen preparation, etc. Local candidate preferred. Apply to Manager, stating qualifications and salary required.

FERRANTI LIMITED require for Vacuum Physics Laboratory Physicists or Engineers, graduates or with equivalent qualifications, preferably with experience of electronic vacuum work or U.H.F. valves. Application forms from Personnel Manager, Ferranti Limited, Ferry Road, Edinburgh, 5.

WELL-KNOWN radio component manufacturer requires Electrical Inspector for their Wiltshire factory. Applicants should have a sound electrical knowledge, and preferably some experience of mechanical inspection. Experience of mass-production inspection is essential. The position offers excellent prospects to an inspector having initiative and the ability to control all inspection in a small radio factory. Box No. 065, "Elec. Engg."

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JUNIOR DRAUGHTSMEN, with radio or light electrical engineering experience, required by large company in East London. Reply, stating details of training, age and experience, to Box 026, "Elec. Engg."

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REQUIRED—Test Engineer with knowledge of high power high frequency valve generators. Box 968, "Elec. Engg."

ELECTRONIC ENGINEER for large industrial concern in north-west London. Applicant must have degree, or equivalent, in electrical engineering and sound theoretical knowledge of electronic control circuits and equipment. Age preferably under 30. Applicant should give full particulars of experience, qualifications, and salary required. Box 049, "Elec. Engg."

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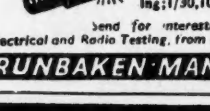

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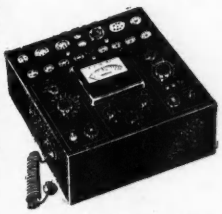

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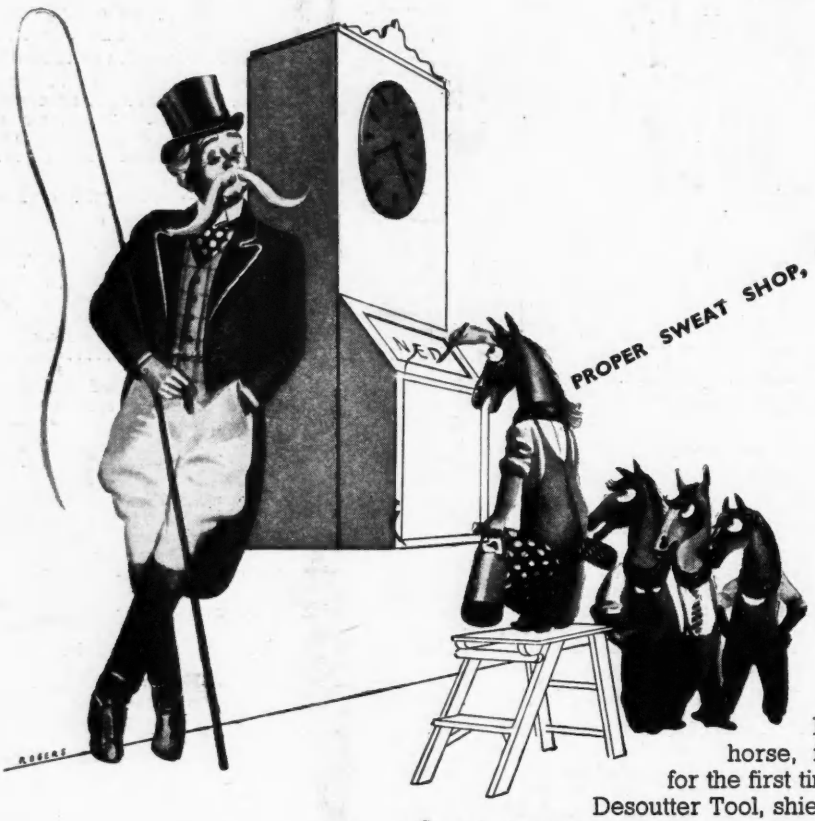

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